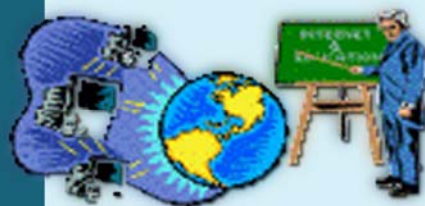


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Aims and Scope

Educational Technology & Society is a quarterly journal published in January, April, July and October. *Educational Technology & Society* seeks academic articles on the issues affecting the developers of educational systems and educators who implement and manage such systems. The articles should discuss the perspectives of both communities and their relation to each other:

- Educators aim to use technology to enhance individual learning as well as to achieve widespread education and expect the technology to blend with their individual approach to instruction. However, most educators are not fully aware of the benefits that may be obtained by proactively harnessing the available technologies and how they might be able to influence further developments through systematic feedback and suggestions.
- Educational system developers and artificial intelligence (AI) researchers are sometimes unaware of the needs and requirements of typical teachers, with a possible exception of those in the computer science domain. In transferring the notion of a 'user' from the human-computer interaction studies and assigning it to the 'student', the educator's role as the 'implementer/ manager/ user' of the technology has been forgotten.

The aim of the journal is to help them better understand each other's role in the overall process of education and how they may support each other. The articles should be original, unpublished, and not in consideration for publication elsewhere at the time of submission to *Educational Technology & Society* and three months thereafter.

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Technology Support for Self-Organized Learners (Guest Editorial)

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This special issue is dedicated to new ways of self-organized learning and its technological support. More and more research in the field of technology-enhanced learning focuses not solely on learners within institutional settings but the topic of “crossing boundaries and contexts” has become something like a hidden agenda. This agenda is connected to the phenomenon that for long years research was focusing on topics like content production and delivery or platform discussions. But with the rise and success of social software the situation has changed. Instead of providing learners with completely pre-defined learning environments a relatively new branch of research and technology-development in the field is focusing on the question how individuals can be supported to plan their learning process on their own and to conduct it within networks of learners with similar competence development goals.

While we do not see self-organized learning as the panacea to solve all educational problems we think that from the perspective of a lifelong competence development need technology-supported and self-organized learning will become a very important factor besides formally organized learning offerings. In the core of this new development we see the empowerment of learners which is enabled by the use of new and advanced learning technologies or new appropriations of old technologies.

Several perspectives on this topic are presented in this special issue. Examples of new technology developments are presented which have been designed and evaluated with the target to enable new possibilities for self-organized learning. Other contributions focus more on the aspect of self-organizing agents as a part of supporting services for lifelong learners. Other contributions study more general questions like the relationship between several motivational aspects of self-organized learning or the question of gender differences in self-organized learning. Several contributions focus on the design and role of the electronic portfolio for self-organized learning, other studies evaluate the implementation of technologies to support self-organized learners in specific contexts. In the next part we will introduce the contributions to the special issue more into depth.

Contributions

Originally the topic of this special issue was the theme of a special track/workshop during the Edumedia Conference “Self-organised learning in the interactive Web” - A change in learning culture?” in Salzburg in May 2008. After the call for papers for a special issue in the *Journal of Educational Technology & Society* we have received 30 contributions from 19 different countries. After a double-blind review 10 papers have been selected to be published in the special issue.

- Matuga presents a study undertaken with 58 high school students taking university-level e-learning courses. The study objective was to investigate the relationship between self-regulation, goal-orientation and study achievement when high school students take part in online college courses.
- Yukselturk and Bultun present a study about gender differences in motivation and learning strategies in synchronous and asynchronous communication. This was done by regarding 145 volunteer students taking part in an online course in Online Information Technology.
- Pata presents a conceptual framework for learning design to support self-directed learning at university courses. The framework is based on ecological psychology and introduces the concepts of “learning spaces” and “learning niches”, collectively shared entities which, in the view of the authors, emerge through individually perceived affordances. The niche-approach is being discussed in the light of traditional learning design approaches. The authors present an empirical study in order to demonstrate the applicability of the learning niche conceptualization.

- Glahn, Specht & Koper focus on contextualised and ubiquitous learning in their contribution. Their paper analyses learner participation as a contextual dimension of adapting graphical indicators of interaction data for engaging and motivating learners in participating and contributing to an open community. The analysis is based on interaction data and interviews with participants in a nine week lasting design study, during which the effect of two indicators on the engagement of the participants in the group activities has been compared.
- Våljataga & Fiedler argue for a course design in which participants are not simply engaged in developing knowledge, skills and orientations in regard to curricular subject matter and the use of technology but actively involved in self-directing intentional learning projects with the support of social media. This perspective is enriched with some empirical data collected from a pilot course taught at Tallinn University, Estonia.
- Louys, Hernández-Leo, Schoonenboom, Lemmers & Pérez-Sanagustín describe in their contribution the self-development of competences within a pilot scenario where several usage profiles and tools from the TENCompetence project are applied. A evaluation methodology is introduced and some results and main findings are discussed.
- In the contribution of Vavoula & Sharples the authors introduce the concept of Lifelong Learning Organisers (LLO). LLOs help learners to capture episodic and semantic aspects of learning events in all kind of learning contexts. Several requirements are defined and refinements for the development of the concept of LLO and also its example implementation KLeOS are discussed.
- Campbell introduces an exploratory descriptive study that examines how the use of an online journaling environment influenced students' capacity to adaptively react to self-determined knowledge about the effectiveness of their method of learning and set learning goals.
- Kirkham, Winfield, Smallwood, Coolin, Wood & Searchwell present a platform on which a new generation of applications targeted to aid the self-organised learner can be presented. The new application is enabled by innovations in trust-based security of data built upon emerging infrastructures to aid federated data access in the UK education sector. Within the proposed architecture, users and data providers (within Virtual Organisations formed for specific learning needs) collaborate in a more dynamic and flexible manner by defining their own data-object-based security policies. This is enabled using a Service Orientated Architecture (SOA) that presents trusted services to ensure that these policies are both applied and enforced.
- Drachsler, Hummel, van den Berg, Eshuis, Waterink, Nadolski, Berlanga, Boers & Koper present a study about the use of a personalised recommender system for navigational support in learning networks. To answer some research questions in respect to efficiency and effectiveness of such a system an experiment is introduced which was set up within an Introduction Psychology course of the Open University of the Netherlands. Around 250 students participated in this study and were monitored over an experimental period of four months.

Acknowledgement

The special track/workshop and this special issue would not have been possible without the generous support of reviewers who have taken their job very seriously and who have provided good comments to the contributors. Here is the full list of reviewers:

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Last but not least we would like to thank the editors of the Journal of Educational Technology & Society, Kinshuk & Demetrios Sampson, for the openness and support during the preparation of this special issue.

We hope you enjoy the special issue.

Self-Regulation, Goal Orientation, and Academic Achievement of Secondary Students in Online University Courses

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ABSTRACT

This study investigated the self-regulation, goal orientation, and academic achievement of 40 secondary students who completed online university courses in the sciences. Students were enrolled in one of three online university science courses. Each course was taught by a two-person team, made up of one university science professor and one secondary classroom science teacher, over a 6-week period. This study explored changes in self-regulation and goal orientation of students enrolled in the online course and the relationship between these factors and student achievement. Student data collected to investigate study questions included an abbreviated version (30-items) of the Motivation Strategies for Learning Questionnaire (MSLQ), collected before and after students completed the online course, and achievement measures (i.e., final grades). Data from application essays and focus interviews, conducted with all participating group members (secondary students, university science professors and the secondary high school teachers), are used to illustrate key findings and probe remaining questions. A description of this program and research resulting from the investigation of online secondary students' motivation, self-regulation, and achievement in online university courses is also presented and discussed.

Keywords

Self-regulation, Goal orientation, Achievement

Introduction

An increasing number of secondary students in the United States are now being required to take an online course as a graduation requirement. The state of Michigan, for example, now requires that all students take at least one online course for graduation from high school. There are also increased funding opportunities in the United States to support initiatives serving secondary students with options to take university courses in areas such as mathematics, science, and foreign languages, while still enrolled in secondary schools. To capitalize on these funding opportunities and increased competition and pressure to entice secondary students to universities, some universities are offering university courses for university *and* secondary school credit. These programs, often called Post-Secondary Programs, may have secondary students attend university part-time or have a secondary classroom educator teaching university courses to secondary students within their secondary classrooms.

The blurring, or erasing, of the line between secondary school and higher education is viewed by some to be very problematic for a variety of reasons. For example, the academic rigor of university course content taught within secondary schools is often called into question as are the qualifications of the secondary teacher to teach university courses. Furthermore, enticing secondary school students to attend university courses in which professors may or, more likely, may not understand the learning and developmental needs of adolescents and fail to provide them with the instructional support and guidance that they need to be successful university students. While this paper does not attempt to weigh in on these matters, they were important considerations for the design of the program illustrated in this paper.

This study investigated potential changes in motivation, goal orientation, and self-regulation of high achieving secondary students as they complete an online university course. Utilizing a pre-test/post-test design, changes in high-achieving secondary students' motivation and self-regulation after they complete an online university course was explored. This cross-sectional study also investigated the relationship between the self-regulation, goal orientation, and academic achievement of high school students enrolled in online college science courses. Data from application essays and focus interviews were also used to illustrate key findings and probe remaining questions. The primary question explored in this study was: What is the relationship between self-regulation, goal orientation, and academic achievement of high school students enrolled in online college courses?

Self-Regulation, Goal Orientation, and Achievement of K-12 Online Learners

The primary purpose of this study was to investigate key variables that have been found by researchers to influence student cognition, learning, and achievement: self-regulation and goal orientation (McCaslin & Hickey, 2001; Pintrich & DeGroot, 1990; Wolters, Yu, & Pintrich, 1996; Zimmerman, 1990, 1994, 2001; Zimmerman & Schunk, 2001). This study also investigated the use of self-regulation by high school students to navigate the completion of online college courses. The study is significant for it provided insight into the relationship between self-regulation, goal orientation and achievement of high school students enrolled in university courses. Furthermore, this study investigated the potential that online teaching and learning affords higher education, by creating a corridor to higher education for high school students.

Student achievement within Brick-and-Mortar learning environments has been found to be influenced by the degree to which a student has effective use of self-regulation, or the ability of students to plan, monitor, and evaluate their own behavior, cognition and learning strategies (McCaslin & Hickey, 2001; Winne, 2001; Zimmerman, 1990, 1994, 2001; Zimmerman & Schunk, 2001). In addition to having the ability to self-regulate, students must also be motivated to use developed or newly acquired self-regulation strategies effectively. Many factors influence the development and use of self-regulation and motivation strategies by students to be self-regulatory and, it is hoped, assist in academic achievement. One such factor is the student's perception of themselves as being intrinsically or extrinsically motivated to engage in learning activities; within educational environments this is known as student goal orientation (Barron & Harackiewicz, 2001; Elliot & Thrash, 2001). Student self-regulation and goal orientation are tightly interwoven constructs that influence student learning and cognition (McWhaw & Abrami, 2001; Pintrich, 1989; Wolters, Yu, & Pintrich, 1996; Zimmerman & Kitsantas, 1997).

Investigations of student cognition and learning have traditionally been conducted within laboratory settings or traditional, learning environments, not online learning environments. The number of K-12 students enrolling in online schools is increasing, given the rate at which K-12 online schools are becoming available to students and parents as an alternative to traditional, Brick-and-Mortar schools (Cavanaugh, Gillan, Kromrey, Hess, & Blomeyer, 2004; Mehlinger & Powers, 2002; Zucker & Kozma, 2003). The number of K-12 online schools, or an exact number of students attending these alternative schools, is difficult to determine and remains somewhat elusive due to the rapidly expanding nature of distance education (Cavanaugh, Gillan, Kromrey, Hess, & Blomeyer, 2004; Zucker & Kozma, 2003).

The investigation described here is important given that technology and the unique environmental constraints of online education have been found to influence the development and use of self-regulation and goal orientation of post-secondary students (Grabe & Grabe, 2001; McMahon, 2002; Nesbit & Winne, 2003; Niemi, Launonen, & Raehalme, 2002; Ng, 2002; Olgren, 1998; Song, Singleton, Hill, & Koh, 2004), yet little is known about the use and development of these key cognitive and learning processes of adolescent online students. A comprehensive review of the research literature found no longitudinal or cross sectional studies that investigated student cognition and learning within K-12 online educational environments.

There may be a variety of factors that have influenced the lack of research on student learning within K-12 online environments (see Zucker & Kozma, 2003). One, research concerning online education has largely been restricted to investigating the cognitive processes and learning of postsecondary students (McIsaac & Gunawardena; Ng, 2002; Song, Singleton, Hill, & Koh, 2004; Zucker & Kozma, 2003). Two, a number of empirical investigations of online learning have sought to compare post-secondary student cognition and learning within traditional, (Brick-and-Mortar) face-to-face and online educational environments (see Bernard, Abrami, Lou, Borokhovski, Wade, Wozney, Wallet, Fiset, & Huang, 2004). Many of these studies report "no significant differences" found between learning online and in traditional classroom environments (Cavanaugh, Gillan, Kromrey, Hess, & Blomeyer, 2004). These studies have been viewed as problematic for a number of reasons most notably, a lack of ecological validity (see Bernard et al., 2004). There is little ecological validity in comparing two environments (face-to-face and online) that have very different affordances and constraints, making it difficult to compare student learning and cognition with achievement outcomes.

The Post-Secondary On-Line Corridor (PSOLC) Project

The Post-Secondary Online Corridor (PAOLC) program was designed to address many of the concerns associated with post-secondary programs mentioned earlier. Three introductory college courses were redesigned by college faculty for the project using National Education Association (2004) Guidelines for Online High School Courses: Biology: Life in the Sea, Introduction to Environmental Science, and Weather and Climate. During the design process, university faculty and instructional designers were aware of and incorporated the US National Education Association's Guidelines for Online High School Courses (<http://www.nea.org/technology/onlinecourseguide.html>). The primary instructional feature incorporated into the online courses was the use of the discussion board to promote student-student and teacher-student interactivity. Two of the three faculty members had prior experience teaching online at the university, none had taught secondary school students.

To assist university faculty in teaching the online courses to adolescents, three secondary school science teachers were selected, from applicants within the immediate geographical area (i.e., within a 40 mile radius), to co-teach each of the online university science courses with university faculty. In addition to being qualified secondary science teachers, the three secondary teachers had advanced university degrees in classroom technology and extensive experience with adolescent learners. All secondary school teachers attended a daylong workshop on online learning and teaching strategies. The secondary teachers also had full access to all course materials and offerings as well as participation in discussion boards, web-chats, and all on-line activities.

Eligible secondary school students were selected from regional secondary schools (i.e., within a 60-70 mile radius) for the PSOLC program. Students were required to apply and be accepted into the university under a 'guest student' provisional status. Students were required to have a recommendation by a secondary school teacher and counselor, a minimum 3.5 out of 4.0 grade point average (GPA), and complete a short survey to assess if they were a "good fit" for online learning. Applications were accepted on a 'first come, first served' basis. The PSOLC program was originally designed to accommodate 90 high school students.

All students participating in the PSOLC program were required to attend an orientation and a final meeting on the university campus. During the initial visit, students attended an orientation to Blackboard (e.g., the course delivery portal), an online learning strategies workshop (one hour), and an orientation to and tour of university services (i.e., the library). The orientation also served as an opportunity for secondary school students to meet with their university instructor and the secondary teacher who would be co-teaching the online course. University courses were taught online as a 6-week summer course. Students, university faculty, and secondary teachers returned to the university campus at the end of the 6th week to share final course projects, discuss student learning outcomes, and complete program evaluations. All fees, including teacher salaries, student tuition and books, were paid for by a state supported grant.

Method

Fifty-eight (58) secondary students were accepted into the program, thirteen (13) students did not start the program, and one (1) student did not complete the program. A total of forty-three (43) students completed the program: twenty-three (23) in marine biology, ten (10) in geology, and ten (10) in environmental science. All secondary school students (junior and seniors) that were accepted for the PSOLC program were invited to participate in this study. Of the 43 students, forty (40) secondary students attended both orientation sessions and the wrap-up session, completing all pre- and post-test measures. The average GPA of the forty participants was 3.8 out of 4.0. Thirty-two (32) participants were female and eight (8) were male. None of the participants had previously participated in an online course.

Instrument and Procedures

Data for this study were collected from four primary resources. Student responses on the essay required for admittance to the PSOLC program were collected to explore student motivation for entering the program. Second, focus group meetings conducted by researchers not affiliated with the PSOLC program were conducted at the

conclusion of the program. Three different focus group meetings were conducted with students, faculty, and classroom teachers are used to illustrate key findings of this study related to program effectiveness and student self-regulation, goal orientation, and achievement. Student evaluations of the three courses completed on the last day of the course were also collected and will be used to illustrate study findings. Finally, the Motivation Strategies for Learning Questionnaire (MSLQ) was administered at the beginning and end of the program to explore changes in student self-regulation and motivation.

MSLQ. The primary instrument used to collect quantitative data used in this study is a modified version of the Motivated Strategies for Learning Questionnaire (MSLQ) (Pintrich, Smith, Garcia, & McKeachie, 1991). This modified version of the MSLQ contained 10 items from the motivation subscale and 20 items from the learning strategies subscales, including subscales regarding resource management. After reviewing various tools used to assess self-regulation and goal orientation (i.e., motivation), the MSLQ was selected for use in this study as a primary assessment tool as it was the most widely used in studies investigating self-regulation, contained several subscales that were of interest in this particular study (namely motivational dimensions and resource management) as they are important to online learning, and its easy translation into an assessment that can be modified to address self-regulatory issues related to online learning.

Reliability coefficients for the motivation scales and the learning strategies scales were calculated by Pintrich, Smith, Garcia, and McKeachie (1993) as .68 and .62 respectively. With the exception of extrinsic goal orientation, all other motivation subscales illustrated significant correlations with final grade by Pintrich, Smith, Garcia, and McKeachie (1993). Further analysis conducted to explore the predictive validity of the MSLQ found that all subscales included on the modified MSLQ for this study were significantly correlated with final grades (Pintrich, Smith, Garcia, & McKeachie, 1993). One subscale for learning strategies, rehearsal strategies, did not illustrate a significant correlation and will not be used in this study. Peer learning and help seeking were not correlated to student grades in Pintrich, Smith, Garcia, & McKeachie's (1993) validation study of the MSLQ but time and study management and effort regulation were significantly correlated to grade.

Ten (10) questions focused upon motivation, including goal orientation, and twenty (20) questions focused upon self-regulated learning topics and activities. Each question requested the student to select from a likert-scale ranging from 1 (not at all true of me) to 7 (very true of me). Students selected their responses to each question on this 7-point Likert-scale. Modified MSLQ's were administered at the start of the online learning strategies session during the orientation visit to the university by the researcher. The modified questionnaire was also administered at the completion of the 6-week online university course, when the secondary students returned to campus. All questionnaires were coded and data was analyzed using SPSS.

Results

With the exception of one student, all secondary students who started the program completed the online university courses. The passage rate for the online science courses was relatively high at 95%; all but two (5%) of the secondary students successfully passed the university online science course. Twenty-three (57.5%) secondary students earned A's (4.0 out of 4.0), thirteen (32.5%) earned B's (3.0 out of 4.0), two (5%) secondary students earned a C (2.0 out of 4.0), one (2.5%) received a D (1.0 out of 4.0), and one (2.5%) student failed the online university course. For data analysis and exploration, students were divided into three groups of high achieving students (the 25 students that earned A's), average achieving students (the 13 students that earned B's), and low achieving students (the 4 students that earned C's, D's, and F's).

Motivation

Analysis of the essays ("Why I want to take an online college course..") submitted by secondary students with their application to the program revealed that 60% of students enrolled in the program as a way to prepare for university; becoming acquainted with the rigor and schedule of college life. Roughly half (48%) described their own interest in science and 43% mentioned that taking an online university course was a to their advantage, potentially reducing the number of courses that they will be required to take at a later time. Roughly one-third (36%) cited the convenience of taking an online course as a reason for enrolling in the program.

The average overall mean for the motivation subscale (10 questions) was relatively high (7=very true of me) before students started the online courses ($M=5.79$, $SD=1.05$) and only decreased slightly by the time students completed the course ($M=5.62$, $SD=1.12$). Paired t-tests were used to explore changes in student responses on individual motivation items.

Three questions from the motivational subscale (Q4, Q6, & Q9) were found to be significantly different before and after students participated in the online course. The mean of student responses to Question 4 “My main concern is (was) getting a good grade in this course” ($t = 2.36$; $p < .05$) decreased from $M=5.79$ ($SD=1.04$) on the pre-test to $M=5.24$ ($SD=1.34$) on the posttest. The mean of student responses on Question 6 “I will receive (received) better grades in this class than most of the other students” ($t = 4.16$; $p < .001$) also decreased significantly after completing the online course (from $M=5.83$, $SD=1.58$ to $M=4.69$, $SD=1.17$). The mean of student responses to Question 9 “I choose course assignments that I (could) learn from even if they don’t guarantee a good grade”, however, significantly ($t = -1.96$; $p < .05$), increased from pre-test $M=4.68$ ($SD=1.37$) to post-test $M=5.21$ ($SD=1.37$).

Pooled means and standard deviations for the ten motivation questions before and after students completed the course are illustrated in Table 1. A repeated measures analysis of variance (ANOVA) was conducted, maintaining a $p<.05$ alpha level, to explore differences in student group means (i.e., high achieving, average achieving, and low achieving) on the motivation subscale items before and at the conclusion of the online course.

Table 1. Means and Standard Deviations on Motivation Subscale by Achievement Level and Pre-Post Online Course

| Achievement Group | Pre-Test M (SD) | Post-Test M (SD) | N |
|-------------------|-----------------|------------------|----|
| High Achieving | 57.78 (5.78) | 59.83 (3.55) | 23 |
| Average Achieving | 56.23 (5.33) | 51.92 (5.10) | 13 |
| Low Achieving | 57.50 (9.88) | 51.25 (9.21) | 4 |
| Total | 57.25 (5.97) | 56.40 (6.15) | 40 |

There were significant differences in student scores on the motivation subscale before and after the online course, $F(1, 37) = 4.00$, $p<.05$ ($\eta^2=.49$). Students in this study scored significantly higher on motivation subscale items before the online course ($M=57.5$, $SD=9.88$) than at the conclusion of the course ($M=51.25$, $SD=9.21$). Furthermore, the achievement level of students interacted with changes in the overall score on motivation items measured before and after the online course, $F(2, 37) = 4.75$, $p<.01$ ($\eta^2=.76$). High achieving students had the highest means on the motivation subscale before ($M=57.78$, $SD=5.78$) and after ($M=59.83$, $SD=3.55$) the online course and differed greatly from their average counterparts (before the course $M=56.23$, $SD=5.33$ and after the course $M=51.92$, $SD=5.10$).

Self-Regulation

While students did not directly cite self-regulatory reasons for selecting the program on essays, 29% of students did mention that they wanted to continue learning throughout the summer as a reason to apply for the program. The overall mean for the self-regulation subscale (20 questions) was moderate (7=very true of me) before students started the online courses ($M=4.5$, $SD=1.46$) and only decreased slightly by the time students completed the course ($M=4.26$, $SD=1.71$). Paired t-tests were used to explore changes in student responses on individual self-regulation items.

Three questions from the self-regulation subscale (Q3, Q11, & Q12), however, were found to be significantly different before and after students participated in the online course. The mean of student responses to Question 3 ($t = 2.75$; $p < .01$), “When I become confused about something I read (was reading) for this course, I go (went) back and tried to figure it out” decreased from before ($M=6.44$, $SD=.85$) to after ($M=5.97$, $SD=1.18$) the online course. The mean of student responses also decreased from the beginning of the course ($M=3.21$, $SD=1.67$) to the end of the course ($M=2.67$, $SD=1.46$) significantly on the question ($t = 2.42$; $p < .05$), “I often found that after I had been reading for this class I did not know what it was all about” (Q11). Mean responses to Question 12 ($t = 3.76$; $p < .001$), “I asked the instructor to clarify concepts I did not understand well,” also decreased after completing the online course (from $M=5.38$, $SD=1.80$ to $M=3.85$, $SD=2.11$).

Pooled means and standard deviations for the 20 self-regulation questions before and after students completed the course are illustrated in Table 2.

Table 2. Means and Standard Deviations on Self-Regulation Subscale by Achievement Level and Pre-Post Online Course

| Achievement Group | Pre-Test M (SD) | Post-Test M (SD) | N |
|-------------------|-----------------|------------------|----|
| High Achieving | 88.61 (10.38) | 83.35 (17.89) | 23 |
| Average Achieving | 91.31 (7.30) | 82.23 (7.82) | 13 |
| Low Achieving | 93.50 (14.15) | 95.00 (9.20) | 4 |
| Total | 89.96 (9.77) | 84.15 (14.82) | 40 |

A repeated measures analysis of variance (ANOVA) was conducted, maintaining a $p < .05$ alpha level, to explore differences in student group means (i.e., high achieving, average achieving, and low achieving) on the motivation subscale items before and at the conclusion of the online course. There were no significant differences in mean scores on the self-regulation subscale before and after the course nor were there any significant interactions found between achievement and pre- and post- means on the self-regulation subscale. However, low achieving students had the highest scores on the self-regulation subscale items before the online course started ($M=93.5$, $SD=14.15$) and after the course ended ($M=95.00$, $SD=9.20$) than either the high achieving or average achieving students at the start or conclusion of the course. Additionally, the scores on the self-regulation subscale of low achieving students increased from pre- to post- while the scores of both high achieving and average achieving students decreased on the self-regulation subscale.

Discussion

In conclusion, this proposal highlights a model for providing secondary students online university courses. While not specifically discussed in this paper, the co-teaching of the university courses by university faculty and a secondary teacher was a successful component of the pilot program. Whether or not this program will serve as a corridor to this particular university for these high achieving secondary students remains to be seen as these students graduate from secondary schools and apply for university. Overall, the program was viewed as successful and is currently under consideration for expansion.

The question of how online learning environments influence motivation, self-regulation, and student achievement is still under investigation. However, results presented here indicate that goal orientation, as indicative of the motivation subscale changes, for secondary students is affected by taking an online university course. Secondary students appeared to enter the online university course with a performance goal orientation, concerned with getting a good grade (Q4 and Q6) or engaging in activities that would get them a good grade (Q9). At the end of the course, however, it appears that students are moving toward a learning orientation.

Overall, student motivation was impacted by taking an online university course, as illustrated by the significant decrease of means on the motivation subscale. There was also an interaction effect between student achievement level and pre- and post- measures of motivation. It appears that students who were high achieving became more motivated and confident in their ability to learn within an online university course when compared to their low and average achieving counterparts, with a significant difference found between the means of high and average achieving students.

Self-regulation subscale findings (Q3, Q11, and Q12) indicate a more complicated view of student's ability to plan, monitor, and evaluate their own learning of university course curriculum. Data indicate that students became less likely to try to figure out material if they were confused, as the semester progressed students found sticking to a schedule more difficult, and they were less likely to ask for help. Overall it appears that high and average achieving students became less confident in their belief in their ability to self-regulate their own learning as the semester progressed. On the other hand, low achieving students became more confident in their belief in their ability to self-regulate their own learning as the semester progressed. Secondary students belief of their own ability to monitor their comprehension (i.e., re-reading, asking the instructor questions, etc.), for example, may stem from an over-estimation of these activities within the face-to-face classroom, challenging university texts and curriculum, or constraints within the online university environments.

This paper illustrates interesting dimensions of the relationship between motivation and self-regulation of online secondary students, a more complete picture of how motivation and self-regulation are related to achievement is an important question still under exploration. As stated, each of the participants in this study were high achieving within the secondary school environment as all had high grade point averages and were ranked, by achievement, as in the top 7% in their secondary class. During this study, data was also collected from each secondary student regarding achievement (e.g., final grade) in the university online course. While a majority (88%) of secondary students received high scores (A's and B's; 4.0 out of 4.0 and 3.0 out of 4.0) for their final grade in the online university course, only a few (4) secondary students did not receive high scores.

The potential significance of this study is apparent on many levels. First, this project may serve as a model for higher education online offerings and programs targeting high school students, an emerging population of online learners. In addition to models for higher education, this project may also serve to inform collaborations between higher education faculty and high school teachers and present a method to scaffold the development of online course instructors.

Second, this project provides the foundation for a future research investigating the relationship between the self-regulation, goal orientation, and academic achievement of online high school students. Since little is known about these important influences on student cognition and learning within online learning environments, this study may provide a foundation for future research within a rapidly growing field. As online education becomes a more viable option for adolescent learners, supporting cognition and student learning within these environments and developing and implementing empirically sound instructional strategies to facilitate the development of cognitive strategies and support learning are critical.

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Gender Differences in Self-Regulated Online Learning Environment

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ABSTRACT

This study analyzed gender differences in self-regulated learning components, motivational beliefs and achievement in self-regulated online learning environment. Sample of the study consisted of 145 participants from an online programming course which is based on synchronous and asynchronous communication methods over the Internet. Motivated Strategies for Learning Questionnaire (MSLQ) was used to assess students' motivation and use of learning strategies. Linear stepwise regression method and multivariate analysis of variance were used to analyze the data. The results of the study indicated that test anxiety explained a significant amount of variance in female students' achievement and two variables (self-efficacy for learning and performance, and task value) explained a significant amount of variance in male students' achievement. It was also found that there were not statistically significant mean differences among motivational beliefs, self-regulated learning variables and achievement in programming with respect to gender.

Keywords

Gender, online learner, motivational beliefs, self-regulated learning strategies

Introduction

Distance education has evolved from print-based correspondence courses to interactive web-based courses over time. Recently, the development of Internet technologies such as the World Wide Web and online communication tools has had an important impact on distance education course. These technologies help educators to create interactive web-based courses which integrate text, graphics, and audio-video materials that can enhance teaching and learning interactivities and also enable learners to continue their education in a more flexible and convenience way (Simonson et al., 2006).

The popularity of this type of distance education format encourage many educational institutions to make decisions about the future of web-based learning at their institution in regard to increasing the number of web-based courses and replacing some traditional courses with web-based courses. This situation is verified by recent institutional survey researches showing that the number of online courses and programs has increased drastically in the recent years (e.g. Allen & Seaman, 2004). Also, it is verified that students learn as effectively when they are attending online courses as compared to when they learn in a traditional face-to-face courses (Simonson et al., 2006).

Distance education environments can be thought to be more democratic than traditional approaches regarding breaking down barriers to higher education for many groups in spite of not solving all their problems. It has been recommended as a good option for especially female students trying to balance multiple roles and demands on their personal life. In view of the fact that distance education allows female having heavy family responsibilities, financial stresses and other works to both stay at home and study (Home, 1998; Kramarae, 2003; Sullivan, 2001).

As a result, it could be said that male and female might be different in several ways while attending in online courses due to their dissimilar responsibilities in their life. Researchers stated that people are not naturally sharply divided into two categories, but, in the literature they agreed that there is a need for more research on gender debate about differences and similarities from learning strategies to performance (e.g. Bidjerano 2005; Chyung, 2007; Lee, 2002; Price, 2006; Rovai & Baker, 2005). This type of study can be constructive for both online course designers and instructors to make rational decisions regarding how to facilitate online instruction and how to minimize gender-related differences in online environments. Therefore, in this paper, we aimed at discussing gender differences in self-regulate learning components, motivational beliefs and achievement in an online course.

Gender Differences in Online Learning

At the beginning years, Internet has been a male-dominated technology. On the other hand, recent studies showed that access to technology and computer literacy level among female and male students have not been appearing problem as done before (Gunn et al. 2003; Ono & Zavodny, 2003). In addition, the gender gap in Internet use has narrowed over the past several years and now greater numbers of female than men have come online (Kramarae, 2003; Rickert & Sacharow, 2000; Price, 2006).

In the literature, gender based differences in education have been recognized as an important focus for research for a long time, especially, since increasing number of online female students. When reviewing gender related studies, the effects of this variable are inconclusive on student experience in distance education. Actually, numbers of studies showed that male and female students experience the online environment differently with respect to several ways, such as, performances, motivations, perceptions, study habits, and communication behaviors (e.g. Chyung, 2007; Gunn et al., 2003; Price, 2006; Rovai & Baker, 2005; Sullivan, 2001; Taplin & Jegede, 2001), on the other hand, several results suggested that gender effects are insignificant (e.g. Astleitner & Steinberg, 2005; Lu et al., 2003; Ory, Bullock, & Burnaska, 1997; Sierra & Wang, 2002; Yukselturk & Bulut, 2007) .

Sullivan (2001) analyzed male and female college students experience in online environment. Significant differences were found between the way male and female students who identified the strengths and weaknesses of the online environment regarding flexibility, face-to-face interaction, shy and quiet students, self-discipline, and self-motivation. Taplin and Jegede (2001) investigated gender differences in factors that contribute to success in online education and these include the areas of organization and the use of study materials, confidence about studies and independent versus collaborative studies. Another study by Price (2006) found that online female students are confident independent learners who are academically engaged and may outperform their male counterparts online. Female place greater value on the pastoral aspect of tutoring and have different interaction styles compared with men. Similarly, Chyung (2007) stated that younger male students' exam scores and younger female students' exam scores were significantly different from each other. In addition, Gunn et al. (2003) mentioned that there are gender differences in styles of participation and contribution in computer mediated communication and they found that women posted and read more messages than their male counterparts on the course bulletin board.

Conversely, Astleitner and Steinberg (2005) discussed meta-analysis of 14 empirical studies dealing with WBL and gender effects. Results suggested that gender effects are insignificant. Ory, Bullock and Burnaska (1997) analyzed gender differences in the use of and attitudes about ALN about one year in a university setting and did not find any differences. Lu et al., (2003) found that graduate students' learning styles, patterns of learning in an online environment, and demographic factors, such as gender did not have any significant impact on learning performance in the class. Yukselturk and Bulut (2007) found that gender variable was unrelated to learning outcomes in online courses. According to Sierra and Wang (2002), findings from several sources (e.g. online observations, survey, and chat transcripts) did not reveal any significant gender differences in the online discussions.

In summary, according to these studies, there are conflicting findings in regard to relations between gender and dependent variables, such as, perception, satisfaction, success, communication behavior in the literature.

Gender Differences in Self-Regulated Learning

The self-regulated learning theories and models emerged in the 1980s. These theories and models generally interrelated with cognitive, affective, motivational, and behavioral dimensions. Pintrich (1995) defined self-regulated learners as (a) attempting to control their behavior, motivation and affect, and cognition, (b) attempting to accomplish some goal, (c) the individual learner must be in control of his actions. Zimmerman and Martinez-Pons (1990) identified 14 learning strategies self-regulated learners used including self-evaluation, organization and transformation, goal setting and planning, seeking information, keeping records, and monitoring, environment structuring, self-consequences, rehearsing and memorizing, seeking social assistance and reviewing records.

In the literature, several researchers mentioned that male and female students demonstrated differences to using self-regulated learning strategies in their learning (e.g. Bidjerano 2005; Hargittai & Shafer, 2006; Lee, 2002; Young & McSparran, 2001; Zimermann & Martinez-Pons, 1990). For example, Lee (2002) found three main gender difference

issues in self-regulated learning strategies from literature: (1) the styles, purposes, and dynamics of social interactions, (2) motivational factors, (3) the styles and frequencies of expression, discussion, or feedback. Similarly, Young and McSporran (2001) found gender differences in their study, such as, online material usage rates, formative and summative assessment completion rates, communication skills, confidence levels, student motivation and learning strategies. They stated that students, especially older women, were more successful and students, especially young men, felt more confident and needed more discipline.

One of the early studies from Zimmermann and Martinez-Pons (1990) examined student differences in self-regulated learning with respect to several variables include gender by the means of interviews with 5, 8, and 11 graders. They discovered that girls tend to employ self-monitoring, goal setting, planning and structuring of their study environment much more often than boys. In another study by Bidjerano (2005), female students surpassed male students in their ability to use some the self-regulated strategies, such as, rehearsal, organization, metacognition, time management skills, elaboration and effort, but, there were no statistically significant gender differences with respect to studying with peers, help seeking, and critical thinking skills. In Hargittai and Shafer's study (2006), female self-assessed their skills significantly lower than men evaluated their skills. Chyung (2007) stated that female students improved their self-efficacy significantly more and scored significantly higher on the final exam than male students.

Some Gender Issue in Turkey

In 2007, estimated population of Turkey is 75 million. Children between 0 and 14 age group constituted 29.8 % of this estimated population. Population between 6 and 21 age group constituted 29.1 % (MoNE, 2007). The primary education was compulsory education which was extended to 8 years in 1997 for children aged between 6 and 14 age groups. Secondary education was also extended to 4 years in 2005. Some demographic data were given in Table 1 for pre-primary through secondary education in 2006 (MoNE, 2007).

Table 1. Some Demographic Data from Pre-primary through Secondary Education in 2005-2006 academic years

| Education | Schools | Teachers | | Students | |
|-------------|---------|----------|--------|----------|---------|
| | | Male | Female | Male | Female |
| Pre-primary | 20675 | 1181 | 23594 | 354252 | 306597 |
| Primary | 34656 | 209366 | 193463 | 5684609 | 5162321 |
| Secondary | 7934 | 110187 | 77478 | 1917189 | 1469528 |
| Total | 63265 | 320734 | 294535 | 7956050 | 6938446 |

After the students have graduated from high schools, they have to enter the university entrance examination to be students in the university. However, the vocational high school student graduates can continue their education in higher vocational education (HVE) directly. After the graduated from this school they can transfer to the university if they satisfy necessary criteria. Table 2 shows that the number of students who are enrolled to higher education institutions and higher educational institutions enrollments by fields of study in 2003-2004 (Turkish Statistical Institute, 2004, p.106).

Table 2. Higher Educational Institutions Enrollments by Fields of Study in 2003-2004

| Education Field | Total | Female | Male |
|---|--------|--------|--------|
| Education | 243477 | 129311 | 114166 |
| Human sciences & art | 73459 | 40880 | 32579 |
| Social sciences, business, law | 619190 | 251267 | 367923 |
| Positive & natural sciences | 102897 | 40912 | 61985 |
| Engineering, production and construction | 113681 | 24555 | 89126 |
| Agriculture, forestry, fishery & veterinary | 33370 | 9187 | 24183 |
| Health & social services | 71429 | 43700 | 27729 |
| Services | 21366 | 5948 | 15418 |

As seen in Table 2 while there are more female students in education, human sciences and art, and health and social services fields than male students, this situation is reversed in other education fields. Also, Table 3 indicates some

demographic data on employed persons who are greater than equal to 15 age group by gender, status in employment, branch of economic activity for 2004 (Turkish Statistical Institute, 2004, p.153). As seen in Table 3, while there are more males in all three economic activities than females. There is a big difference in industry area in the favor of females.

Table 3. Demographic Data on Employed Persons by Gender, Status in Employment and Branch of Economic Activity for 2004 (Numbers should be multiplied by 1000)

| | Total | Agriculture | Industry | Services |
|----------------------|--------------|--------------------|-----------------|-----------------|
| Males | 16 023 | 4 101 | 4 206 | 7 716 |
| Regular Employee | 7 352 | 91 | 2 746 | 4 515 |
| Casual employee | 1 461 | 245 | 701 | 516 |
| Employer | 971 | 92 | 290 | 588 |
| Self employed | 4 805 | 2 613 | 380 | 1 814 |
| Unpaid family worker | 1 443 | 1 059 | 89 | 285 |
| Females | 5 768 | 3 299 | 811 | 1 657 |
| Regular Employee | 1 927 | 9 | 601 | 1 315 |
| Casual employee | 338 | 152 | 86 | 101 |
| Employer | 49 | 7 | 6 | 36 |
| Self employed | 583 | 427 | 71 | 86 |
| Unpaid family worker | 2 870 | 2 703 | 47 | 120 |

Method

Research Hypotheses

The purpose of the study is to examine gender differences in self-regulated online learning environment with respect to motivational beliefs, self-regulated learning components and achievement. Motivational beliefs consist of 6 variables: intrinsic goal orientation, extrinsic goal orientation, task value, control of learning beliefs, self-efficacy for learning and performance, test-anxiety. Self-regulated learning components include 2 variables: cognitive strategy use and self-regulation. The following null hypotheses were tested:

- Motivational beliefs and self-regulated learning components together do not explain a significant amount of variance in female students' achievement in an online programming course.
- Motivational beliefs and self-regulated learning components do not explain a significant amount of variance in male students' achievement in an online programming course.
- There is no statistically significant mean difference between male and female students with respect to motivational beliefs, self-regulated learning components and achievement in an online programming course.

Description of Online Course

Online Information Technologies Certificate Program (ITCP) is one of the first Internet Based Education Projects of the Middle East Technical University, which is a reputable, English-medium university at the capital of Turkey. Online ITCP is based on synchronous and asynchronous communication methods over the Internet. The online certificate program was started in May 1998, and it is still active. The main aim of the online ITCP is to train participants in the IT field. Also, it provides opportunities for people who would like to improve themselves in advanced IT area and desire to make progress in their existing career (Isler, 1998).

This online certificate program provides online lecture notes, learning activities and visual aids to the participants in the courses. One instructor and one assistant are dealing with each course. Also, each course has an e-mail address, discussion list and chat sessions to provide interaction between instructors and students, and students and students. At the end of each semester, there are face-to-face sessions for each course (Isler, 1998). Introduction to Computer Programming with C is one of the programming courses in this online program. The aim of this course is to teach students who have no knowledge about computer programming by using C programming language. The basic

programming concepts and applications are given to students with the help of examples. At the end of the course, students will be able to write variant basic C programs. Some topics of the course are as follows: variables, operations, conditionals, loops, arrays.

Subject of the study

The study included 145 volunteer students (October-December 2006, October-December 2007) who attended at the online computer programming course of the certificate program, Middle East Technical University in Ankara, Turkey. All students of the certificate program were computer literate and had an intermediate level of English due to the requirements for enrollment to the program. In this study we utilized the convenience sampling. According to Fraenkell and Wallen (2000), the sample that is easy accessible is convenience sample and the obvious advantage of this type of sampling is that it is convenient.

Originally, one hundred ninety students were registered to the program; however this study included the ones who were volunteers to participate in the study. The number of male participants (N= 101) was greater than the number of female participants (N=44), and the participants' age ranged from 20 to 40 and above. The majority of the participants' ages were between 20 and 29 (Male N=77, Female N=38). The majority of the participants were university graduates and undergraduate students.

Instrumentation

In the literature, students' motivation and use of learning strategies generally were measured by the MSLQ, which is a self-report questionnaire developed by Pintrich and colleagues (1991). It was adapted into Turkish by Hendricks, Ekici and Bulut (2000). Its pilot study was conducted by administering the scale to the students enrolled in Department of Foreign Languages Education at METU, Turkey. The MSLQ, a self-report, 7 point-Likert-scaled instrument was designed to assess motivational beliefs and use of learning strategies in an online programming course. The positively related items to the component were scored from "not at all true of me" as 1 to "very true of me" as 7. However, the negatively related items were reversed to a positive direction for scoring purposes. The MSLQ consists of two scales: (1) motivation and (2) use of learning strategies (Pintrich et al., 1991). The first scale has three components: value, expectancy, and affective. It has 31 items. Value components consist of intrinsic goal orientation, extrinsic goal orientation and task value. Expectancy components consist of self-efficacy for learning and performance, and control of learning beliefs. In affective component there is only test anxiety. In the learning strategies scales there were two components: (1) cognitive and metacognitive strategies and (2) resource management strategies. It has 50 items. The first component consists of rehearsal, elaboration, organization, critical thinking and metacognitive self-regulation. The second one was formed by time and study environment, effort regulation, peer learning and help seeking.

Table 4. Cronbach Alpha Values for the Motivational Beliefs and Self-Regulated Learning Components

| Scales | Abbreviation | Items | Male | Female | Whole |
|---|--------------|-------|-------|--------|-------|
| Motivational beliefs | | | | | |
| Intrinsic goal orientation | Intr | 4 | 0.623 | 0.594 | 0.615 |
| Extrinsic goal orientation | Extr | 4 | 0.670 | 0.640 | 0.656 |
| Task value | Tskv | 6 | 0.741 | 0.675 | 0.720 |
| Control of learning beliefs | Cont | 4 | 0.677 | 0.637 | 0.665 |
| Self-efficacy for learning & performance | Slef | 8 | 0.848 | 0.850 | 0.851 |
| Test anxiety | Tanx | 5 | 0.742 | 0.728 | 0.737 |
| Self-regulated learning components | | | | | |
| Cognitive strategy use | Stru | 19 | 0.860 | 0.831 | 0.852 |
| Self-regulation | Slrg | 16 | 0.803 | 0.780 | 0.798 |

In this study, self-regulated learning components consist of cognitive strategy use and self-regulation. The cognitive strategy use score was obtained by computing the sum of the scores of the rehearsal, elaboration, organization and

critical thinking. The self-regulation scores were obtained by adding the scores of meta-cognitive self-regulation and effort regulation. In Ozturk's (2003) study the reliability coefficients for the eight variables ranged from 0.53 and 0.89. In the present study, the reliability coefficients were given in Table 4.

Data Collection and Analysis

The subject was selected from students attending in the online programming course of online certificate program in this study. The online programming course starts with the face to face meetings in the university campus. In the face-to-face meetings, the course instructors explain the course topics briefly and students have a chance to meet with their classmates and instructors. Then, students attend this course online about three months. After three months, students come to university campus again for face-to-face traditional exams. The MSLQ (Motivated Strategies for Learning Questionnaire) was distributed by the researchers to the students at the end of the course. The structures of the course given in this program were not changed and the researchers did not affect the students or instructors of the course during the study.

In this study, the students' achievement score, which was another dependent variable, was based on six assignments and the traditional final examinations (paper based test) at the end of the online course. Prior to conducting the study institutional permission was obtained. Also, students were informed about the study and their participation was voluntary and that they had the right not to participate and the right not to answer all questions about this study.

During analyzing of the results, the descriptive statistics such as mean and standard deviations of subjects both female and male were calculated for the MSLQ scale scores and achievement scores. Linear stepwise regression analysis was used to assess how well achievement can be explained in terms of motivational beliefs (intrinsic goal orientation, extrinsic goal orientation, control beliefs, task value, self-efficacy, and test anxiety) and self-regulated learning components (cognitive strategy use, and self-regulation). Furthermore, Multivariate Analysis of Variance (MANOVA) was used to analyze mean differences between male and female students regarding motivational beliefs, self-regulated learning components and achievement.

Results

Three null hypothesis of the present study were tested at the significance level of 0.05.

Results of Regression Analysis for Female Students

The first hypothesis of the present study can be stated as "motivational beliefs and self-regulated learning components together do not explain a significant amount of variance in female students' achievement in an online programming course." It was tested by using linear stepwise regression analysis. Before testing this hypothesis its assumptions were checked. Multicollinearity assumption was examined by using Pearson product moment correlation. The relationship between self-efficacy and task value was greater than 0.70. The others were less than this value. Tabachnick and Fidell (2001) stated that the correlation coefficients among independent variables should be less than 0.70. If not, they suggested two procedures. One of them was omitting the one of the variables in the analysis. As seen in Table 5, the relationship between self-efficacy and task value was greater than 0.70. The scatter plots also showed that there was high linear correlation between these variables. Therefore, task value was removed from the analysis. This predictor was preferred because in the literature there are many studies which support the relationship between achievement and self-efficacy (e.g. Joo, Bong, & Choi 2000; Wang & Newlin, 2002; Yukselturk & Bulut, 2005). Hence, linear stepwise regression analysis was performed by using 7 predictor variables (Intr, Extr, Cont, Slef, Tanx, Slrg and Stru). Some results of linear stepwise regression analysis were given in Table 5.

As seen in Table 5, only test anxiety had statistically significant contribution in explaining the variance in female students' achievement and approximately, 14 percent of variance in female students' achievement was explained by this variable ($R^2=0.139$, adjusted $R^2=0.119$, $F(1,44)=6.96$, $p=0.012$).

Table 5. Results of Linear Stepwise Regression Analysis for Female Students' Achievement

| | | | | | |
|-------------------------|--|-----------------------|--|----------|----------|
| Multiple R | 0.373 | | | | |
| R ² | 0.139 | | | | |
| Adjusted R ² | 0.119 | | | | |
| Standard Error | 19.139 | | | | |
| | df | Sum of Squares | Mean Square | F | p |
| Regression | 1 | 2548.093 | 2548.093 | 6.956 | 0.012 |
| Residual | 43 | 15751.377 | 366.311 | | |
| Total | 44 | 18299.470 | | | |
| | β Unstandardized | Standard Error | β Standardized | t | p |
| Test Anxiety | -1.204 | 0.457 | -0.373 | -2.637 | 0.012 |

The other variables were excluded from the equation of predicting achievement because they did not have a significant contribution to variance in achievement ($p > 0.05$). Female students' programming achievement can be predicted from the equation below:

$$\text{Ach}_{\text{female}} = -0.373 \times \text{Tanx}$$

Regression Analyses Results for Male Students

The second hypothesis of the present study can be stated as "motivational beliefs and self-regulated learning components together do not explain a significant amount of variance in male students' achievement in an online programming course". Before testing this hypothesis its assumptions were checked. Multicollinearity assumption was satisfied except both Slrg-Stru and Intr-Tskv. Their Pearson product moment correlation coefficients were greater than 0.70 for these pairs. They did not satisfy the criteria stated by Tabachnick and Fidell (2001). The scatter plots also showed that they had high relationship between these predictors. One of the variables in each pair was removed from the analysis. Slrg was preferred as a predictor variable because there were many research studies which stated the relationship between self-regulation and achievement (Yukselturk & Bulut, 2007; Zimmerman, 1990; Zimmermann & Martinez-Pons, 1990). Tskv was selected as a predictor instead of Intr in the analysis because the correlation coefficient between Intr and Slef was also quite close to 0.70 and their scatter plot graph indicated that there was almost high correlation between these predictors. Hence, linear stepwise regression analysis was accomplished by using 6 predictor variables (Extr, Tskv, Cont, Slef, Tanx and Slrg). Some results of linear stepwise regression analysis are given in Table 6.

Table 6. Results of Linear Stepwise Regression Analysis for Male Students' Achievement

| | | | | | |
|-------------------------|--|-----------------------|--------------------|-----------------------------|--------------------|
| Multiple R | 0.297 | | | | |
| R ² | 0.088 | | | | |
| Adjusted R ² | 0.070 | | | | |
| Standard Error | 19.755 | | | | |
| | df | Sum of Squares | Mean Square | F | p |
| Regression | 2 | 3707.622 | 1853.811 | 4.750 | 0.011 |
| Residual | 98 | 38246.531 | 390.271 | | |
| Total | 100 | 41954.153 | | | |
| | β Standardized | t | p | R² Change | p- F change |
| Slef | 0.373 | 3.060 | 0.003 | 0.045 | 0.034 |
| Tskv | -0.264 | -2.164 | 0.033 | 0.044 | 0.033 |

As seen in Table 6, two variables (self-efficacy for learning and performance, and task value) had statistically significant contribution in explaining the variance in male students' achievement ($R^2=0.088$ adjusted $R^2=0.070$, $F(2,100)=4.750$, $p=0.011$). Approximately 9 percent of the variances were explained by these variables. Self-efficacy for learning and performance was the strongest significant predictor of male students' achievement, accounting for 4.5 % of the variance in Ach (R^2 change=0.045, $F(1,99)=4.644$, $p=0.034$). Task value accounted for an additional 4.4 % of the variance in Ach (R^2 change=0.044, $F(1,98)=4.683$, $p=0.033$). The other variables were excluded from the equation of predicting achievement because they did not have a significant contribution to

variance in achievement ($p>0.05$). Male students' programming achievement can be predicted by using the following equation:

$$Ach_{male} = 0.373 \times Slef - 0.264 \times Tskv$$

Multivariate Analyses Results for Male and Female Students

In order to test last hypothesis regarding mean difference between male and female students, MANOVA was used with gender as independent variable, and six motivational beliefs, two self-regulated learning variables, and achievement in programming (totally 9) as dependent variables. Wilks' λ revealed that there was no an overall significant mean difference among the mean scores of the nine variables with respect to gender (Wilks' $\lambda = 0.067$; $F(9,146)=1.84$, $p>0.05$).

In the results of the study, there was no statistically significant mean difference between female students and male students with respect to motivational beliefs, self-regulated learning components, and programming achievement. Mean and standard deviations were given in Table 7.

Table 7. Means and Standard Deviations of Measures of the Study as a Function of Gender and All Subjects

| Variables | M _{female} | SD _{female} | M _{male} | SD _{male} | M _{total} | SD _{total} |
|-----------|---------------------|----------------------|-------------------|--------------------|--------------------|---------------------|
| Intr | 5.23 | 1.04 | 5.51 | 0.94 | 5.42 | 0.98 |
| Extr | 4.27 | 1.21 | 4.24 | 1.27 | 4.25 | 1.24 |
| Tskv | 5.81 | 0.74 | 5.89 | 0.79 | 5.87 | 0.77 |
| Cont | 5.69 | 0.89 | 5.67 | 0.89 | 5.68 | 0.89 |
| Slef | 4.86 | 0.95 | 5.18 | 0.94 | 5.08 | 0.95 |
| Tanx | 3.90 | 1.26 | 3.63 | 1.27 | 3.71 | 1.27 |
| Stru | 4.73 | 0.75 | 4.59 | 0.84 | 4.63 | 0.82 |
| Slrg | 4.88 | 0.77 | 4.66 | 0.81 | 4.73 | 0.81 |
| Ach | 61.88 | 20.39 | 60.63 | 20.48 | 61.02 | 20.39 |

As seen in Table 7, it can be stated that male and female students had the same tendency in motivational beliefs and self-regulated learning components. Furthermore, they were undecided in Extr and Tanx. Lastly, both gender had equivalent achievement in programming online course.

Discussion

It has been recognized that online learning courses and programs are in progress. The expansion of online learning environments has opened doors for learning that are closed for many individuals, who are unable to attend traditional classes. Most studies of online learners reported that more female than male are enrolled in courses delivered at a distance (Kramarae, 2003; Rickert and Sacharow, 2000). Researchers stated that these female students are trying to deal with or balance multiple roles such as mother, wife, and employee. In other words, it can be stated that male and female might be different in several ways while attending in online courses due to their dissimilar responsibilities in their life. The growing awareness of the impact of gender differences validates the study of gender and online learning as an important research subject in the literature (e.g. Bidjerano 2005; Chyung, 2007; Lee, 2002; Price, 2006; Rovai & Baker, 2005). Similarly, this study focused on gender differences in self-regulated learning components, motivational beliefs and achievement in self-regulated online learning environment. The results indicated that there was no statistically significant mean difference among motivational beliefs, self-regulated learning variables and achievement with respect to gender. Moreover, test anxiety variable explained a significant amount of variance in female students' achievement and two variables (self-efficacy and task value) explained a significant amount of variance in male students' achievement.

In this study as an example of gender related study, one of the main results expressed that female and male student's motivational beliefs, self-regulated learning variables and achievement did not differ in online programming course. These findings were not entirely surprising because they replicated many of the existing findings from the literature. Although several researchers stated that female and male students experience the online environment differently,

gender in many learning environment were not reported as significant variable for many years in the past (e.g. Astleitner & Steinberg, 2005; Lu et al., 2003; Ory, Bullock & Burnaska, 1997; Sierra & Wang, 2002; Yukselturk & Bulut, 2007). It might be stated that the gender related differences were not found in several samples and communities.

In distance education, learners are mature enough and they are aware of their responsibilities. Likewise, the participants' age ranged from 20 to 40 and above and the majority of the participants' ages were between 20 and 29 in this study. Also, the online certificate program accepts only students who are studying or graduated from two-year colleges or four-year universities and the participants are expected to be computer literate and have an intermediate level of English. These properties of students might not reveal the presence of gender-related differences in self-regulated learning components, motivational beliefs and achievement in online course. Moreover, the lack of gender-related differences might be partly explained by the nature of the online course. In this online course, the basic programming concepts and applications are taught with help of synchronous and asynchronous communication methods over the Internet in three months. Gender-related differences might be seen in the advance courses or courses that last more than three months.

Another result of the study showed that test anxiety explained a significant amount of variance in female students' achievement. Female students with higher levels of test anxiety received lower grades in the online programming course. A number of studies have reported negative correlations between test anxiety with performance (Chapell et al., 2005; Niemczyk & Savenye, 2005; Ozturk, Bulut & Koc, 2007). In this online course, the student performance was assessed by traditional face to face exam including multiple choice questions that might cause test anxiety. Actually, most traditional forms of assessment are not appropriate for testing learning outcomes that online courses are promoting (Mason, 2002). The most useful application of assessment in online environments is formative and self-assessment strategies rather than summative and graded assessment. Online technologies allow for a wide range of assessment techniques that can be used to assess learning: selected response assessments, constructed response assessments, virtual discussions, concept mapping, e-portfolio assessment, writing, field experiences, individual and group projects, informal student feedback, peer assessment, and self-assessment (Benson, 2003; Reeves, 2000).

According to another result of the study, two variables (self-efficacy and task value) explained a significant amount of variance in male students' achievement. Self-efficacy refers to the belief an individual possesses about ability to perform a task (Bandura, 1986). Also, there is a significant and positive relationship between self-efficacy and performance in online education (Joo, Bong, & Choi 2000; Wang & Newlin, 2002; Yukselturk & Bulut, 2005). Another variable was task value that refers to the student's perception of how important the task is to him or her (Pintrich et al., 1991). The results showed that task value beliefs were correlated positively with self-efficacy, cognitive strategy use and self-regulation, like in the literature (Pintrich et al., 1991; Pintrich, 1999). However, task value beliefs were correlated negatively with male students' achievement in this online programming course. This particular finding contradicted with previous research stating that this variable was positively correlated with academic achievement (Bong, 2001). This negative correlation might be explained by not meeting some male students' expectations related to course assignments, projects since task value is also degree to which activities, assignments, and projects seem useful (Pintrich & Schunk, 1996).

As a summary, additional importance has been given to gender issues as distance education has been extensively marketed to women since correspondence courses (Kramarae, 2003). Likewise, this study analyzed gender differences in self-regulated online learning environment. The results showed that there was no statistically significant mean difference among variables with respect to gender and also the amount of variance in male and female students' achievement can be explained with several variables.

Recommendations

Based on the results of this study, it cannot be recommended that females should be treated differently in online courses in comparison to males. However, it may be possible to make some recommendations about the different behaviors of male and female students that may contribute to enhanced achievement of some of these students. In the literature, there are several factors affecting student achievement in online education courses include an individual student's personality characteristics. One way of looking at individual student characteristics is to look at their motivational beliefs and use of learning strategies. With understanding factors affecting student achievement in

online course, it is easy to identify learning activities and support services that some students need more. For example, in this study, female students with higher test anxiety may have thoughts that might impede their study habit or cognitive activity and so they may receive lower grades in exams. Therefore, in addition to traditional ways of assessments, alternative assessment techniques should be considered while designing courses especially in online environments to assess student learning. Another example with self-efficacy beliefs in this study, male students who did not have any information about course contents or did not have adequate computer experience or confidence might be at-risk for low grades in the online course. Self-efficacy perceptions might be assessed before online courses in order to identify learners who are potentially at risk for low performance. Then, appropriate activities and feedback might be designed for assisting these students to complete the course successfully.

Some potential limitations of this study also should be taken into consideration while discussing the results since gender differences in self-regulated learning components, motivational beliefs and academic achievement were analyzed in an online course. The study population consisted of only Turkey students attending in online certificate programs, which limits the generalizability of the results. Extending the population to various courses, programs and universities could produce different results.

Another possible study might be conducted about relationships of interaction types, collaborative activities that are more prepared in online learning environments and student characteristics (motivational beliefs and learning strategies) together. Also, other variables (i.e. attitude, satisfaction, learning style) can be examined with these selected components together. The experimental approach can be used to identify causal relationships among variables. Finally, all the motivational and behavioral learning-strategy variables were measured with a self-report instrument and this study did not include qualitative data to confirm the quantitative results. In other words, extending the study to qualitative data could further support the results of the current research and produce more in depth implications.

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Modeling spaces for self-directed learning at university courses

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ABSTRACT

This paper conceptualizes the theoretical framework of modeling learning spaces for self-directed learning at university courses. It binds together two ideas: a) self-directed learners' common learning spaces may be characterized as abstract niches, b) niche characteristics are collectively determined through individually perceived affordances. The implications of these ideas on the learning design are discussed. The empirical part demonstrates the learning niche formation at the master course „Self-directed learning with social media“ at two consequent years. The results of the affordance determination were used to characterize and develop the learning spaces that support self-directed learning with social media. The realization of the learning niche at two following years demonstrated that students used different social media tools for putting a similar types of affordances of the learning niche in action. This finding suggested that affordance-based niche descriptions would allow flexibility and learner-centeredness but simultaneously might enable to identify a common emergent learning space and make it reusable for modeling environments for self-directed learning courses.

Keywords

Learning design; Learning niches; Affordances, Self-directed learning

Introduction

New developments in the Web provide individuals with various opportunities of personalizing the tools and services, and performing self-directed learning in an open and social context with their personal learning environments (Klamma, et al., 2007). Social software enables people to actively reflect, publish and share learning experiences; gain awareness and monitor other learners, communities and networks; publicly store and maintain the evidences of their learning; and personally retrieve socially gathered information (O'Reilly, 2005; Constantinides & Fountain, 2008). Learners can autonomously combine various tools, material- and human resources into personal learning environments and enter with their personal environments to various learning activities and courses (Pata & Väljataga, 2007; Fiedler & Pata, 2009).

However, the traditional e-learning design models that determine in advance the standardized learning environment components, instructions, and the expected outcomes for all learners (see Passerini & Granger, 2000) fall behind in promoting self-directed learning with personal learning environments at institutional settings (Attwell, 2007; Underwood & Banyard, 2008; Pata & Väljataga, 2007; Fiedler & Pata, 2009). Recently some learning design models for promoting self-directed learning (van Merriënboer & Sluijsmans, 2008) and considering the utilization of learner-defined spaces (Kirschner, Kreijns, Beers & Strijbos, 2004) have been proposed. Yet, these models lack to consider learners as agents who constantly monitor, shape and adapt their personal learning environments in respect to the community space, leaving feedback of their activity preferences to the space. Learners' active contribution that impacts the learning environment and -activities of the courses needs more attention while modeling e-learning designs for self-direction.

In this paper the aspects of an ecological learning design model are proposed. This framework considers mutual interaction between the bottom-up formation of course environments by learners, and the emergence of certain commonly perceived learning spaces and niches that constrain learners' selection of their personal learning environments. This paper provides some empirical evidence how learner-defined learning space descriptions could be used for determining the learning environment and activity design. It is discussed how common learning spaces for self-directed learners may be characterized, shaped and utilized at the targeted university courses as part of an ecological learning design framework. The empirical findings from the master level educational technology course with social software tools are used for demonstrating some aspects of this framework.

Self-direction with personal learning environments

In near future fundamental transformations are predicted in enterprises. New post-industrial organizations will be disaggregated (Snyder, 2006) and not based on monolithic industrial knowledge-management systems. Rapid developments in economy and social sphere will extensively rely on design-orientated, information-rich small creative companies that work in a new flexible mode of producing cultural goods and services, and drive the innovation (Fasche, 2006). The rapidly changing business and social environments require the development of constantly learning and creative, independent, responsible and autonomous people. With the increased use of social tools in learning and work processes, social shaping of these tools will become more democratic and dependent of people (Burns & Light, 2007). All this has implications on the e-learning systems used at universities, and to the learning design principles. Nordgren (2006) has listed important themes that must be solved in educational institutions in order to provide the future learning environment: students owning their learning; standards and curricula that guide rather than dictate; constructivist teaching strategies that empower students; trust and adult supervision; democracy and empowerment; and Global Workforce Competence: making schooling relevant to the work-place. Universities should provide experiences with shared power (democracy) and responsibility, developing learners' self-directing competences of learning and working (Fischer, 1999) in dynamically changing and globally intertwined industrial environments, workplaces and private lives outside the classroom, where institutionally offered monolithic software systems are not available. In this paper the self-directing competence is interpreted through the definition of Knowles (1975) and Brockett and Hiemstra (1991). Self-directing is diagnosing and formulating needs, identifying resources, choosing and implementing suitable strategies and evaluating outcomes (Knowles, 1975) in the learning activities that always take place in a certain social context inseparable from the social setting and other people (Brockett & Hiemstra, 1991).

New courses must specifically develop learners' self-directing competences (Fiedler, Kieslinger, Pata & Ehms, 2009): i) the ability of diagnosing their learning needs in the light of given performance standards, ii) formulating meaningful goals for own learning (Kieslinger & Pata, 2008), iii) developing and using a wide range of learning strategies appropriate to different learning tasks, carrying out a learning plan systematically and sequentially (eg. Knowles, 1975; Pressley 1995), and iv) diagnosing, monitoring performance and identifying resources and tools for accomplishing various kinds of learning objectives (Fiedler & Pata, 2009). On-demand learning with personally owned tools (eg. portfolios, personal learning environments) can offer students the opportunity to plan their own learning trajectory by providing them a certain amount of freedom to choose what they want to learn (i.e., selecting a topic) and how they want to learn this (i.e., selecting particular learning tasks) (Kicken, Brand-Gruwel, van Merriënboer & Slot, 2008; Attwell, 2007; Underwood & Banyard, 2008; Fiedler et al., 2009). People need to obtain the competences of thinking new ways of their personal and social learning- and work-environments – foreseeing the effective functionalities of social spaces, and managing and developing them as systems that support their personal and collective learning and work objectives.

Learning spaces and -niches

The main idea in supporting self-direction allows learners entering to the courses with their personally favored learning environments, which will be partially integrated for collaborative tasks (Fiedler & Pata, 2009; Fiedler et al., 2009; Pata & Väljataga, 2007; Tammets, Väljataga & Pata, 2008). Since each learner may have different personal goals and experiences, these environments differ. Consequence of this bottom up construction is that learning environment of the course is ambiguous and hardly describable by means of tools, functionalities and services. Therefore, in this paper the *learning space* term has been conceptualized as an alternative for describing learning environments in the courses that promote self-directed learning in collaborative settings. This learning space is not the collection of tools and resources in the environment but integrates people who interact with the entities from external space.

Recently, several largely tool-centered approaches of supporting self-directed learning with computer-based personal learning environments (Attwell, 2007; Wilson, 2008; Johnson & Liber, 2008), portfolios (Kicken, Brand-Gruwel, van Merriënboer & Slot, 2008) or distributed social software (Fiedler & Pata, 2009) have been described. However, some authors have suggested that self-directed learners develop more abstract individual cognitive learning spaces (Underwood & Banyard, 2008), which contain various material and human resources that they activate in their goal-directed action. Magnani (2008), and Magnani and Bardone (2008) use the term cognitive niche to mark the

distributed space that people create by interrelating individual cognition and the environment through the continuous interplay through abductive processes in which they alter and modify the environment.

Previously, the niche term in e-learning was used to emphasize individual's accommodation with its environment which was created for them by instructors or developers. Draper (1998) has explained that all successful computer aided learning technologies rely on the learners' fit to their ecological niche. He assumed that instructors' skilled administration for the teaching and learning using the technology enables the niche-based success. Draper interpreted niches as personally defined, rather than community defined spaces, and failed to recognize the niche influence on people through feedback loop. He assumed that: "If you want to be better adapted it is no good studying anybody else's niche, nor any other niche than the one you are in right now. It is also a long shot studying other people's solutions, although (as convergent evolution shows) just occasionally old solutions may be good for you too."

The ecological framework, suitable for self-directed learning with social software-based personal learning environments, calls for revising these Draper's (1998) assumptions. Before elaborating the niche term for learners it is useful to explain in more detail, what the niche term means in natural science. Hutchinson (1957) defined a niche as a region (n-dimensional hypervolume) in a multi-dimensional space of environmental factors that affect the welfare of a species. Niche is an abstract space defined by the life activities of species. While each individual contributes to the formation of the niche and uses niche information in their activities, the niche as an abstract formation exists only through the activities of many individuals of this species.

Thus, the learning space term that is used in the ecological learning design model of this paper describes common abstract cognitive learning spaces of several learners at one course. The learning space term is not a description of the material system or a particular learning environment. Space is determined by users' activities and perceptions. The learning space term denotes an abstract composition of dynamically changing *learning niches*. Learners, who interact with the environment and respond to the expected interactions that they trust the environment would offer for them, constantly determine niches. Niches exist for certain populations and communities, who are involved in similar teaching and learning activities. Niches come into existence and may be identified when many individuals actualize personal or collaborative cognitive learning spaces for the same purpose with certain frequency at certain time period. This could be illustrated with the example of learners using social bookmarking or RSS aggregation services for maintaining their information flow. Through their personal learning environment they contribute and rely on certain culturally defined properties of the space - bookmarking and tagging information publicly, and constant updates in RSS flow. These activities are, therefore, characteristic to the information management niche of many learners. Within one abstract learning space for a certain group several learning niches may appear, which may be commonly actualized in different phases of the goal-directed learning activity. While conducting individual research, the new bookmarks may be tagged and filed or other persons' bookmarks and tags could be explored, and the community's contribution as one niche characteristic would be less crucial for the learner. However, while collaboratively collecting bookmarks for a project, and determining the meaning dimension of these bookmarked materials with tags for creating community's folksonomy as a common meaning-dimension, the contribution of the community is vital for successful usage of social bookmarking services. Therefore, the individuals and community members using a social bookmarking tool as one element in their personal learning environment, may perceive two different activity possibilities in their learning space. In one case using social bookmarking may support effectively individual information management, in another case it obtains a group information management possibility. Learners would perceive two different niches in their learning space, depending of their learning objectives.

The environmental factors that influence learners and define learning niches are not limited to external material resources (tools, artifacts, people), the type of their structural of organization (eg. networked, distributed, dynamically changing), or cultural context. The formation of learning niches is also dependent of internal learner-specific factors (goals, motivation, previous experiences, learning culture etc.). Specific learning niches (eg. for individual and collaborative activities) may exist within one learning space and the learners would switch from one niche to another in the course of action (Pata, in press).

One important aspect in the learning space formation is its ecological nature. Maturana and Varela (1992) coined the concept enaction that consolidates the divide through interdependence of the perceiver and the environment. They assumed that as we enact within a world, we are necessarily also embodied in it: knowledge involves creative cognition arising from the interconnections between our bodies, language, society, and the world. Thus, in the course of goal-directed action each learner perceives and actualizes only certain aspects of the environment. Presumably,

this actualization is two-directional. First, individual goals and previous experiences constrain the environmental aspects that are perceived beyond the others. Simultaneously, the environment as a complex system with other learners and resources actualizes certain goals and cultural behaviors for the learner. This individually directed perspective-taking process enables social selection of certain learning-related aspects of the environment beyond the others. The scope, how much certain aspects will be actualized by a larger group of learners, defines the learning space for them. Thus, niches and more large learning spaces, consisting several potential niches, are emergent and socially constructed as a result of ecological interrelations of individuals with their learning environment aspects.

Mathematically, niches are abstract multi-dimensional spaces. These spaces appear as environmental gradients, which indicate for the users these areas of the space, which are potentially more suitable for certain activities. In general, niche gradients have been described as peaks of the fitness landscape of one environmental characteristic (Wright, 1931) concentrated in space and time (Müller, 1998). Each gradient has certain ecological amplitude, where the ecological optimum marks the gradient peaks where the organisms are most abundant. Niche gradients can be visualized in two-dimensional space as graphs with certain skewness and width, determining the ecological amplitude. The shape of each fitness graph for certain learning-related characteristic could be plotted through considering the abundance of a group of learners actualizing and benefitting of this characteristic. In the learning niches each gradient is ecologically emergent of many learners' interaction with their environment. Each learner participates in the niche generation and gains from the niche individually by perceiving commonly preferred characteristics of the learning space for self-directed action.

The niches of the learning space may also facilitate and constrain each other. Hutchinson (1957) distinguished the 'fundamental' and the 'realized' niches – the former exist as the complex of all necessary environmental characteristics for certain species, the latter is formed under the pressure of all the currently available environmental characteristics in the competitive conditions with other species. Various actors and resources in learning situations have influence to each other, which would shape the niche. The 'fundamental learning and teaching niche' term applies for all possibly usable dimensions of software tools and services, artifacts and people that can aid for specific type of learning for certain learners, while the 'realized learning niches' will form under the constrained conditions of resource availability in the course of action of these learners. The paradox in using learning niche term in the learning design model is that for planning the fundamental niches the variety of realized niches for certain community must be identified in advance or in the course of action. Planning for the fundamental learning niches for a new course, the previous similar community niches from earlier courses may be used as the starting-points in the design. In this paper we use niche term to determine this part of the learning space that self-directed users perceived while working with social software.

Conceptualizing affordances as niche gradients

These niche gradients that make up learning and teaching spaces, may be considered as equivalents of learning affordances because they are defined mutually in interaction both by the learner and the surrounding system. Gibson (1979) originally defined affordances as opportunities for action for an observer, provided by an environment. He suggested that a niche is a set of affordances that constrains possible behavior with respect to what we are able to do in a certain niche.

The environment in affordance conceptualization does not merely involve material objects and tools in the environment. Referring to Albrechtsen, Andersen, Bodker, & Pejtersen (2001), in Gibson's view, it is the very mutuality between actor and environment that constitutes the basis for the actor's perception and action. Hence, the primary unit of analysis is not the actors nor the environment as distinct categories, but the total ecosystem of actors and environment. Chemero (2003), a follower of Gibson's ecological psychology, suggests that affordances are features of whole situations (meaning the actors are part of this situation). Michaels (2003) claims that perceiving affordances is more than perceiving relations, but it brings attention to the action-guiding information and sets up action systems to act. For example, Kreijns, Kirschner, and Jochems (2002) and Gaver (1996) describe affordances as the 'properties' of a collaborative learning environment that act as social-contextual facilitators relevant for the learner's social interaction. Barab and Roth (2006) have noted that connecting learners to ecological networks, where they can learn through engaged participation, activates the affordance networks. Affordance networks, in contrast to the perceptual affordances described by Gibson, are extended in both time and space and can include sets of perceptual and cognitive affordances that collectively come to form the network for particular goal sets. According to

Barab and Roth (2006) affordance networks are not entirely delimited by their material, social, or cultural structure, although one may have elements of all of these; instead, they are functionally bound in terms of the facts, concepts, tools, methods, practices, commitments, and even people that can be enlisted toward the satisfaction of a particular goal. In this way, affordance networks are dynamic socio-cultural configurations that take on particular shape as a result of material, social, political, economic, cultural, historical, and even personal factors but always in relation to particular functions. Barab and Roth (2006) assume that affordance networks are not read onto the world, but instead continually ‘transact’ (are coupled) with the world as part of a perception-action cycle in which each new action potentially expands or contracts one’s affordance network. In the ecological learning framework, affordances are considered the relations between particular aspects of the situations and people planning or taking action – the perceived possibilities for both thinking and doing, what learners evoke and signify during their actual interaction with an artifact or tool and with each other. Learning affordance determination by users at individual level defines at community level niche gradients for learning-related activities.

Affordances emerge and potentially become observable in actions what people undertake to realize individual or shared objectives. Any individual conceptualizes learning affordances personally, but the range of similar learning affordance conceptualizations may be clustered into more general affordance groups. Magnani and Bardone (2008) stress that human and non-human animals can “modify” or “create” affordances by manipulating their cognitive niches. In the Soviet school of thinking, Ilyenkov (1977) has coined the idea of ‘ideality’ that is of relevance if to describe the ideas how affordances are evolving and culture-defined. He noted that objects acquire an ideal content for certain activities not as the result of being accessed by an individual mind, but by the historically developing activities of communities of practice. The ideal exists in the collective not in the individual mind as a set of given rules, practices, tools and artifacts. Thus, relying on Ilyenkov we can say that communities interacting similarly within certain environmental surroundings for certain learning goals would define various ideal or fundamental niches. The creation of these niches is of ecological nature and they are not part of the material learning environment per se.

Since in the learning design models the choice of the software tools plays an important role, niches may be defined by the frequency each learning affordance is perceived useful for the community when making use of the certain tool among all other available or chosen tools. For example, when using aggregators and microblogging tools most learners might actualize and perceive the presence of ‘filtering the social awareness’ affordance. However, few individuals may actualize ‘filtering the social awareness’ affordance while using weblogs, social network or social bookmarking tools. Thus, the fitness peak for ‘filtering the social awareness’ would be situated among the aggregators and microblogging tools, and sloping in case of using weblogs, social network or social bookmarking tools.

Aspects of an ecological learning design model

The idea to use affordances in the learning design is not new. For example Kirschner et al. (2004) suggested an affordance based and learner-centered interaction design model. According to their interaction-design sequence model, the affordances must be derived from learners’ behavior, translated to the affordances by developers, tested in activity through learner’s perception and action, and then evaluated on the basis of effectiveness on learning. This model involves the following steps:

1. Collecting learner experience: What do the learners actually do and what they want to do?
2. Supporting affordances: How can we support what learners do and what affordances they need?
3. Considering constraints and conventions: What are the physical, logical and cultural limitations encountered?
4. Constructing the learning design and testing it in action: How do the learners perceive the support?
5. Controlling learners’ experiences: How do the learners actually use the support?
6. Learning: What have the learners actually achieved?

Kirschner’s and his associates (2004) model is centered to the learning environment development. Their application of affordances instead of functions and services in the environment design makes the design model ecological. However, they do not particularly emphasize learners’ self-monitoring and -evaluation activities, and the task of monitoring for affordances is left for instructional designers. Thus, this model is only partially supporting self-directed learning principles and is not suitable for guiding the learning situations into which learners enter with various self-managed personal learning environments.

Alternatively, van Merriënboer and Sluijsmans (2008) have outlined an instructional design model that focuses on self-direction in the learning environment design by balancing certain learning environment properties and tasks externally of learners. Their basic claim is that all environments for complex learning can be described in terms of four interrelated components: (1) learning tasks, (2) supportive information, (3) procedural information, and (4) part-task practice. They assume that known principles to reduce individual learner's cognitive load and increase germane load while performing complex learning tasks (eg. simple-to-complex ordering and fading-guidance strategies, high variability and self-explanation prompts) are also useful to enable their self-directed learning skills (i.e. assessing own task performance and selecting future tasks). This model controls self-directed learning through pre-determined part-task practice in which self-direction and gradual taking control of the task choice is prompted. The new Web culture, however, relies more heavily on learners' initiative in choosing their own learning tasks, and appropriate learning environments, and instructors must face the emergent bottom-up learner-triggered task situations, which are complex and ambiguous from the very beginning (Fiedler & Pata, 2009; Fiedler et al., 2009). Thus, this design model too needs some elaboration.

Pata and Väljataga (2007), and Fiedler and Pata (2009) have suggested that learners' role in noticing and negotiating the affordances of their individual and joint learning space in self-planned, -monitored and -evaluated activities must be part of the learning design model. Their approach leaves more room for learners' self-direction but points out many critical aspects in prompting and supporting these learners' activities externally while facilitator is planning and maintaining the course environment and tasks.

For promoting self-direction with self-chosen tools at university courses the elaborated affordance-based learning design model should take one step further from the previously introduced models. The ecological learning environment formation in which the affordances have the binding role between individuals and niches, and activities of self-directing one's tool-choice in interaction with the environment are parts of the same integrated system, which provides new basis for the learning design framework. This ecological learning design framework introduces two ideas: a) self-directed learners' common cultural learning spaces may be characterized as abstract niches, and the facilitators may use these niche descriptions in learning design instead of learning environment properties and functions, b) niche characteristics are collectively determined through individually perceived affordances during the application of personal and collaborative learning environments for self-directed activities.

The basic steps of an ecological learning design framework for supporting self-directed learning in new social Web are:

1. Define the learning and teaching niches for your students by collecting their affordance perceptions of their learning spaces dynamically in the course of action.
2. To support the conscious self-managed development of learner-determined spaces, provide students with the tools of visualizing and monitoring their activity-patterns and learning landscapes, and enhancing public self-reflection and collaborative grounding of learning affordances.
3. To maintain coherence of the current niche, introduce cycles of re-evaluation of learning affordances of the learning space within your course.
4. Try to influence the niche re-emergence by embedding activity traces and ecological knowledge relevant to evoke affordances for certain niches or select activity systems where these traces are naturally present.
5. Use same social learning environments repeatedly to gain from feedback left as activity traces and embodied knowledge of earlier learners.

An ecological learning design framework can be explained as an iterative continuous cycle. In one phase one learning community will dynamically define their learning niche (or the niche of similar previous community /course/ could be used). The conditions for the re-appearance of this learning niche with different sets of learner-selected tools in the activities of another similar learning community must be supported. For this, the activity- and meaning traces created during the real activities of initial community in that niche must be preserved, and made available for the next communities. Therefore the new learning support systems at the university courses must contain community-based activity accumulation and visualization possibilities.

An ecological learning design framework involves cycles of grounding the learning affordances during the activities. Cook and Brown (1999) assume that affordances should be conceptualized as a dynamic concept. In an ongoing interaction with tools, artifacts, and other actors, we are not only affected by the dynamic situational changes but also by our previous experiences. Thus, our personal dispositions strongly influence what affordances we actually

perceive in a given situation at a certain point in time. The learning affordances are never fixed and stable but ecologically emergent and may be influenced by many criteria (see Barab & Roth, 2006). The new learning design framework resides on the idea that niche construction in social software environments happens through the dynamic determination of learning affordances by many individually or collaboratively acting learners and teacher. Learners must develop a compatible understanding of the affordances of a given setting to make effective performance possible. This is true both for facilitator and learners who want to collaborate. The similar application of tools, functioning rule-system and distribution of labor that support the realization of certain objectives in the learning space are realized upon the commonly perceived affordances. To support dynamic niche shaping, the visualization, self-reflection and monitoring of personally perceived affordances in activities at certain tool- and service-landscapes must be enabled for students and facilitator.

Social software based learning environments already integrate a feature of tag-clouds to get overview of the meanings of certain communities, using the bottom-up method. The possibility of bottom up collecting of information of activities, that the social software based learning spaces are most commonly used for, is still missing. Therefore, it is difficult to visualize how a community behaves in its niche. Affordances, which interrelate the goal-directed activities and various components of the learning environment, serve as suitable candidates for defining spaces socially in a bottom up manner. Using visual schemas and narrative descriptions of activity patterns and learning landscapes together with public self-reflection as tools for self-directed planning, is one, but labor-consuming possibility how to make affordances explicit for individuals and negotiate the affordances of common spaces. The application of this method in the courses enables learners and facilitators to define the dynamic changes in the niche for achieving better coherence as a community with certain learning aims. This type of learning involves design-oriented thinking and promotes the competence development that is expected from learners in future workspaces as Fasche (2006) has suggested. For grounding affordances of the niche, various self-reflection tools (blog, aggregator, shared whiteboard etc.) can be suggested, which help the community to monitor the niche formation. However, it is expected, that in future, the missing possibility of bottom-up collecting and viewing user-defined affordance information in social Web would be technologically solved.

Table 1. Basic differences between the traditional and ecological learning designs

| Traditional learning design | Ecological learning design |
|---|---|
| Learning environment consists of tools, people and resources. | Learning space is an abstract niche emerging in the course of evoking affordances, while learners interact. |
| Software tools and services make up learning environments independent of learners and facilitators being present. | Learning spaces and their user communities have interdependence and cannot exist without each other outside the activity setting. |
| The functionalities of software tools and services for learning and teaching are an objective part of the systems and appear similar to all learners and the facilitator. | In action each learner and facilitator evokes subjectively different learning affordances, depending of the environment, and the learning culture. |
| Certain learning and teaching paradigms can be embedded and fixed as conceptual designs within the learning systems. | Learners and facilitator participate ecologically in the niche construction, changing the learning spaces and causing the evolution of learning and teaching paradigms. |
| Relevant learning environment properties can be identified before conducting the learning activity and the learning environment can be prepared for students. | Learning space affordances emerge among learners and facilitator during the activity in the course of interaction. |
| Instructions in narrative and visual form can be embedded to the environment to transfer useful learning environment properties and activity tasks to students. | Instructions should be left as activity traces and ecological knowledge that learners and facilitator can actualize as part of their action plans. |

Certain instructions can be used to lessen the difference of learners' and facilitators' perception and expected affordances in the learning space. Instructional texts may contain anticipated affordances for different kinds of action-potentialities, but the emphasis of an instruction must be on triggering learner's action plan so that they might start using the elements in the learning space similarly as the instructor and a larger learning community believes is efficient. This could be realized by leaving relevant activity traces to the learning space or choosing the learning space in which such activity traces were provided by the larger community of learners. New social Web environments provide such an opportunity without too much effort of preparing activity traces by the instructor.

Vicente's (2002) Ecological Interface Design offers an example of using this principle in learning design. His approach suggests that an important design rationale is the notion that actors would directly perceive the state of affairs in the environment. In order to aid this, the interface of a system must be transparent in the sense that the deep structure of the work was accessible to direct perception as an affordance space in a Gibson's sense.

The theoretical framework of using learning niches as part of the design assumes that they are defined ecologically and may start guiding learning processes when learners and facilitator would dynamically actualize learning and teaching affordances in action, make them explicitly observable, monitor and negotiate about them. The same set of learning affordances as a functional niche can be put into action with different sets of social software tools chosen by the learners and facilitator in the course of action. For example learners can use the affordance-based decision-tools to select tools in their personal learning environments (Väljataga, Pata, Laanpere, & Kaipainen, 2007). The main aspects, how ecological learning design differs from traditional learning designs (see Passerini & Granger, 2000), are presented in Table 1.

The ecological learning design framework application at the self-directed learning course

In the following chapters the niche formation and the application of an ecological learning design framework principles are illustrated based on the master level course for self-directed learning. The iterated design-based research was conducted, considering the ecological learning design elements. The tasks for students involved composing descriptions of individual and collaborative social Web landscapes and activities for self-directed learning while using these landscapes. Public self-reflection of affordances of these learning environments was prompted. The facilitators used affordance data collected from students for planning the learning activities for the following course.

1. The study sought answers to the following research questions:
 1. What characterizes the learning niche for self-directed learners who use social software?
 2. How the course niches differ at consequent years, and are niches replicable with different toolsets?
 3. How could the learning niche descriptions be applied in developing the course design?

Firstly, it was expected that the niche description from the self-directed learning course would reveal affordances for self-direction in individual and collaborative settings while using social software. Knowing these affordances of the learning niche would help to keep some structure in the learning design of the course. Secondly, it was predicted that it would be possible to define the fundamental learning and teaching niche for self-directed learning purposes, and re-create the similar learning niche at the consequent years of the course, while giving the students certain freedom of planning their activities and personal and collaborative learning environments from social software tools. This would demonstrate that niche characteristics might be described and reused effectively, meaning that in the learning design model, the learning space can be conceptualized as a niche with n-dimension of affordances, rather than the fixed set of tools similar for all learners. It was assumed that to replicate the niche, students would be granted the freedom to use different toolsets and resources for constructing their personal and group learning environments. Third assumption was that using the bottom-up method to define the learning niche could be used to diagnose if the learners had actualized the learning and teaching potential of social software tools similarly like the facilitators presupposed, relying on their own experience with social software. This diagnosis could enable them to change the course tasks towards better supporting self-directed learning.

Methods

Sample

The participants of the study were master students of Tallinn University, mainly from Institute of Informatics who participated in the course „Self-directed learning with social media“. The two groups of students were involved in two consequent studies. In the first study, held in spring 2007, 25 second-year master students participated at the course. In the fall 2007, 28 first year master students participated at the course. They were organized into groups at some learning assignments. The master students of the Tallinn University, Institute of Informatics originated from heterogeneous backgrounds – there were practicing teachers of different subjects or informatics, educational technologists of different governmental and military institutions and private enterprisers. Thus, they all had needs for

different competences, and their contact with social media had been quite minimal so far. Due to the authentic settings of the study, convenient sampling was used. Therefore, the conclusions from this research must be regarded in the particular contextual setting. Two facilitators of the course were involved in research.

Course settings

At the first year (Case I) the course was run aiming to develop primarily the learners' competencies of using social software environments for planning learning landscapes and activity patterns, both for personal and collaborative use (see Väljataga, Pata, Tammets, in press). After the course learners' perception of their learning niche was studied to make corrections in the teaching emphasis of the course. At the second year (Case II) the focus of the course was concretized, emphasizing more the development of self-directed learning competences through individual and collaborative activities with social software (see Tammets, Väljataga & Pata, 2008). This meant mainly that the self-reflection on personal learning contracts in weblog was integrated as one of the learning tasks in addition to the previous tasks that were used at the first year of the course.

The course consisted of three face-to-face contact days, meantime learners were asked to do independent work, either individually or in groups. At contact days, facilitators gave theoretical lectures and modeled practical competences of using different social media tools and services for educational purposes. The evaluation data from Case I was used to elaborate some aspects of learning with social media tools for teaching in Case II. Learners were expected to get practical experiences with different social media tools in order to plan their individual and collaborative learning environments and activities with those tools.

The same course environment was reused at both cases without removing the contents of the previous course. The general planning of the course' learning environment was the following. The distributed web-based learning environment of the course was conducted dynamically under learners' eyes with their active participation. Every student individually developed his or her personal distributed learning environment and described and tested it in action. In order to perform collaborative learning tasks, learners had to combine their learning environments, to conduct collaborative activities. Creating such joint learning environment together with learners, improved the learners' competencies of conceptualizing the affordances of the learning space similarly as the facilitator and other learners, and enabled the facilitator to make corrections in the learning environment in accordance with the learners' perception of affordances. Students could see, that their role was equal to the facilitator, and monitor, how each member was contributing to the development of the distributed learning environment of the course.

The central feedback and learning material service of the course was a blog at *Wordpress.com* provider, which was maintained by two facilitators (<http://kaugkoolitus.wordpress.com>). The primary function of the blog was organizing learning materials and assignments, it also served as the feedback channel between learners and facilitators. Students' and facilitators' comments at the blog were visible for the students in Cases I and II.

The second part of web-based distributed learning course environment was the social bookmarking service *Delicious.com* (<http://delicious.com/mii7008>), where facilitators collected bookmarks of the materials related to the course. The *Slideshare.net* tool and *Splashcast* were used to present slideshows, which were also embedded to learning materials at the course blog. The third central tool of the course was a shared aggregator in *Pageflakes.com* provider (<http://www.pageflakes.com/kpata/12983138>). This aggregator enabled to integrate different distributed course tools, using feed and mashup technologies. The course aggregator collected into the shared place the feeds from course weblog and learners' weblogs, enabling the monitoring between learners themselves and between facilitators and learners (Väljataga, Pata & Tammets, in press). The tagcloud feed from the course bookmarks, and the mashed feed from social bookmarks accounts were pulled to the aggregator. Students in Case 2 could also view the aggregated page of the course in Case 1.

The students' distributed learning environments consisted of blog, social bookmarking service and slideshare accounts, web-based office software, wiki, instant messaging services, and aggregators. Individual blog was a compulsory tool for each student. Secondly, using *Delicious.com* for bookmarking information with shared tag was required. The rest of the tools were not optional. Some students used very actively wiki, some web-based office service, and social repositories of *Flickr.com* and *Youtube.com*. This kind of usage of tools and services supported the personalized mediation of self-directed learning and constructing the personal learning environments that were

useful for their owners. Every learner could make the choice of the most suitable tools for her/him. Learners had a chance to decide what is useful for them, and they could use only those tools, and not merely the services, that teacher had proposed as the most suitable. The shared learning environments of the groups were developed as part of one of the course assignment. In general individual blogs, collaborative writing/drawing environments like *wiki*, *google.docs*, *Vyew.com* or *Bubble.us*, and instant messaging services like *Gabbly.com*, *MSN.com* and *Skype.com* were used for constructing group environments, but the final settings of groups differed from each other. The learners formed groups, then selected tools what they needed in order to complete assignments, they planned the group work, selected the tools suitable to everyone in the group, decided how to organize the communication between the group members, and how to divide the responsibility. In other words, the assignment developed their competencies, which would be required in their professional and academic life. Most of the learners could not meet face-to-face between the contact days, which facilitated online interaction with assignments.

For the tasks, learners were expected to draw visual schemas of individual and collaborative learning environments and activity diagrams, describe these schemas in self-reflections, explaining the main learning affordances related to the schemas, and write in blog an essay about their personal development in the end of the course. Learners had freedom to choose relevant objectives and setting for their activities and learning environment. For example, some learners visualized learning environments for their work settings (eg. the model of information management in radio-station, the model of communication for multi-national kindergarten groups and parents, self-directed learning environment for a master student to communicate with supervisor etc.). Drawing the schemas of activities, and distributed individual and collaborative learning environments, and reflecting about them in blog were considered important activities for giving learners the tools to plan and monitor the realization of their tasks.

Data collection and analysis

Schemas of personal and shared distributed learning environments and activity diagrams were collected from learners' blogs. Each figure was accompanied by narrative descriptions mentioning several learning affordances in relation with the tools the student(s) used for activities and for constructing distributed learning landscapes. Essays and schemas from learners' blogs were used as research instruments in the design-based research process. In that kind of authentic settings it was important to use such data gathering instruments that enabled to collect the learners' perceptions of learning affordances without intervention. Thus, the same data-collection instruments could serve simultaneously as a natural part of learners' assignments, supporting their competence development.

The analysis of 53 individual and 10 collaborative activity- and learning landscape descriptions was conducted. For the study two researchers analyzed from schemata and narratives, investigating, what kind of tools were part of the learners' distributed learning environments and what kind of tools they used for planning activities. It was categorized, which learning affordances the students perceived in relation to every tool in their learning environment in two Cases. The relationship of the learning affordance with the tool(s) was categorized using binary system. The categorization scheme separated each affordance according to its belonging to Case 1 or 2. Each affordance was listed only once in relation to mentioning it with the certain tool. The main tool categories were: blog, wiki, chat tools (*MSN*, *Skype*, *Gabbly*), email, search engines, RSS aggregator, social bookmarking tools, forums, co-writing tools (eg. *zoho* or *google documents*), co-drawing tools (eg. *Vyew*, *Gliffy*), and social repositories of *Flickr* and *Youtube*. These were selected because these tools were mostly in use during the course and they also appeared at students' schemas frequently. These data reflected specifically the learning affordance perception of students in this course (beginner users of social software), and cannot be broadened to the perception of learning affordances of the active social Web users in various settings.

The learning affordances were consequently categorized into specific types of similar affordances: assembling, managing, creating, reading, presenting, changing and adding, collaborating and communicating, sharing, exchanging, searching, filtering and mashing, collecting, storing, tagging, reflecting and argumentations, monitoring, giving tasks and supporting, asking and giving-getting feedback, and evaluating (see Appendix 1). These types were deduced from the main verbs the students tended to use in their learning affordance descriptions. The differences between the two researchers' categorization were resolved after comparison and discussions.

SPSS 16.0 was used for statistical analysis. To show the preferred interrelations between software and affordance types, the Principal Component Factor analysis was performed with the frequency table of software and affordance

types. To compare the two cases on the basis of software and affordance-types, the ANOVA analyses with affordance distribution between the affordance-types and software-types were calculated. The Chi square analysis was performed with same data. To visualize learning niches the Cross-tabulation of affordance types and tool-types was used. The frequency of learning affordance types was found for each software type. Each learning affordance type eg. 'searching' was considered as a variable defining the niche. Niches were conceptualized as the collections of environmental gradients with certain ecological amplitude, where the ecological optimum marks the gradient peaks where the organisms are most abundant. Over all activity/landscape descriptions the optimum for certain learning affordance type was calculated, dividing the frequency of this affordance type per certain software type to the total frequency of certain learning affordance type for all the software types. The results were plotted as the niche maps with wireframe contour figures of MS Excel.

Results

Self-directed learners' learning niche affordances with social software

For characterizing the functional learning niche components for self-directed learners who use social software, two approaches were taken: qualitative text analysis of affordances, and quantitative factor analysis of affordance types and software. Initially all the learner-defined affordances from Cases 1 and 2 were categorized under certain affordance types that could be distinguished from each other. The affordance types were named by the most common activity verbs represented in this category. The affordance types with examples provided evidence, that learners perceived various indicators of self-directed learning when working with social software. The affordance types with distinguishable examples are presented at Appendix 1.

Secondly, Principal Component Factor Analysis (Table 2) was used to demonstrate that learners relate certain affordances types with certain software. 13 factors were identified, which explained 60 % of the system. Certain software types (eg. blog, co-writing and -drawing tools) were represented in several components of the factor analysis, indicating that students perceived various affordance dimensions when working with them. Others (search engines, social repositories, social bookmarking systems) were represented only in one component, presuming that learners perceived narrower action potentialities with them. Since these results were collected from the course of beginner users of social software, different factor structure may emerge with the more experienced users of social Web environments. Following factors were found:

- I. Searching with search engine (Google)
- II. Collecting and sharing in social repositories (Flickr, Youtube)
- III. Exchanging with email and chat (Skype, Gabble, MSN)
- IV. Storing and tagging with social bookmarking tools (Delicious)
- V. Filtering, mashing and monitoring (but not reflecting) with aggregator (Pageflakes, Netvibes)
- VI. Collaborating and communicating with collaborative publishing tools (Pbwiki, Zoho and Google documents, Vyew and forums)
- VII. Presenting, giving tasks and supporting (but not monitoring) with co-drawing tools (Vyew, Gliffy)
- VIII. Giving tasks, supporting, asking, giving and getting feedback (but not sharing, reflecting and arguing) with blog (Wordpress)
- IX. Changing and adding and storing (but not collaborating and communicating, and sharing) with co-drawing tools (View, Gliffy)
- X. Creating and reflecting (but not assembling) with co-drawing tools (View, Gliffy)
- XI. Monitoring (but not collecting, managing, collaborating and communicating) with blogs (Wordpress)
- XII. Evaluating (but not assembling and monitoring) with blogs (Wordpress)
- XIII. Reading and reflecting (but not monitoring) with forums and blogs (Wordpress)

The comparison of two courses: software types and affordance types

To clarify if the two courses differed by the use of software and by the use of affordances, two ANOVA analyses were performed. The comparison of used software types at Cases 1 and 2 (Table 3) demonstrated, that if the course design allows flexibility and freedom of using personal tools, different groups of self-directed learners would bring

to the course significantly different learning environment components for performing same tasks. This complicates planning the learning environment in advance as part of the learning design.

Table 2. Rotated Component Matrix Components for affordance types with social software (Note. the factor names are presented in the text above)

| Rotated Component Matrix Components | | | | | | | | | | | | | |
|-------------------------------------|------|------|------|------|-------|------|-------|-------|-------|------|-------|-------|-------|
| | I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII | XIII |
| Variance % | 5.79 | 5.55 | 5.50 | 5.46 | 5.37 | 5.05 | 4.26 | 4.14 | 4.04 | 4.0 | 3.74 | 3.63 | 3.59 |
| Eigenvalue | 2.34 | 1.85 | 1.75 | 1.60 | 1.57 | 1.48 | 1.32 | 1.21 | 1.18 | 1.13 | 1.09 | 1.06 | 1.03 |
| Search | .865 | | | | | | | | | | | | |
| <i>Google</i> | .856 | | | | | | | | | | | | |
| <i>Flickr</i> | | .839 | | | | | | | | | | | |
| <i>Youtube</i> | | .809 | | | | | | | | | | | |
| <i>Email</i> | | | .774 | | | | | | | | | | |
| <i>Chat</i> | | | .753 | | | | | | | | | | |
| Exchange | | | .510 | | | | | | | | | | |
| <i>Bookmarks</i> | | | | .746 | | | | | | | | | |
| Tagg | | | | .740 | | | | | | | | | |
| Store | | | | .520 | | | | | -.327 | | | | |
| <i>Aggregator</i> | | | | | .813 | | | | | | | | |
| Filter/mash | | | | | .732 | | | | | | | | |
| <i>Co-writing</i> | | | | | | .710 | | | | | | | |
| <i>Wiki</i> | | | | | | .703 | | | | | | | |
| <i>Co-drawing</i> | | | | | | .381 | -.356 | | -.279 | .234 | | | |
| Present | | | | | | | -.730 | | | | | | |
| Feedback | | | | | | | | .713 | | | | | |
| Tasks/support | | | | | | | -.464 | .549 | | | | | |
| <i>Blog</i> | | | | | | | | .347 | | | .176 | -.224 | .334 |
| Change/add | | | | | | | | | -.720 | | | | |
| Collaborate | | | | | | .428 | | | .436 | | -.238 | | |
| Share | | .243 | | | | | | -.316 | .374 | | | | |
| Create | | | | | | | | | | .737 | | | |
| Assemble | | | | | | | | | -.541 | | | .336 | |
| Reflect | | | | | -.353 | | | -.241 | .432 | | | | .230 |
| Manage | | | | | | | | | | | -.614 | | |
| Collect | | .210 | | | | | | | | | -.520 | | |
| Monitor | | | | | .310 | | .311 | | | | .448 | .226 | -.224 |
| Evaluate | | | | | | | | | | | | -.837 | |
| Read | | | | | | | | | | | | | .714 |
| <i>Forum</i> | | | | | | .307 | | | | | | | .443 |

Note. Software types are presented in Italic

Table 3 presents which software types were perceived useful when affordances were described at two cases – Spring 2007 (Case I) and Fall 2007 (Case II). It was found that the main difference in Case II compared with Case I was students' higher preference on focusing at the these software types that enable constructing jointly distributed learning spaces for collaborative activities.

Table 3. ANOVA of the distribution of learning affordances between software types in Case I (N=381) and Case II (N=285) descriptions

| Software types | Case | N | Mean | StdDev | df | Mean square | F | Sig |
|------------------|------|-----|------|--------|----|-------------|--------|---------|
| blog | I | 121 | 0.32 | 0.46 | 1 | 13.658 | 60.236 | 0.001** |
| | II | 173 | 0.61 | 0.48 | | 0.227 | | |
| wiki | I | 19 | 0.05 | 0.22 | 1 | 0.155 | 2.626 | 0.10 |
| | II | 23 | 0.08 | 0.27 | | 0.059 | | |
| chat | I | 23 | 0.06 | 0.24 | 1 | 1.336 | 15.258 | 0.001** |
| | II | 43 | 0.15 | 0.35 | | 0.088 | | |
| social bookmarks | I | 42 | 0.11 | 0.31 | 1 | 0.935 | 7.711 | 0.006* |
| | II | 53 | 0.19 | 0.39 | | 0.121 | | |
| aggregator | I | 87 | 0.23 | 0.42 | 1 | 1.069 | 6.896 | 0.009* |
| | II | 42 | 0.15 | 0.35 | | 0.155 | | |
| email | I | 21 | 0.06 | 0.23 | 1 | 0.107 | 1.729 | 0.18 |
| | II | 23 | 0.08 | 0.27 | | 0.062 | | |
| search engine | I | 30 | 0.08 | 0.27 | 1 | 0.042 | 0.532 | 0.46 |
| | II | 27 | 0.09 | 0.29 | | 0.078 | | |
| co-writing | I | 15 | 0.04 | 0.27 | 1 | 1.440 | 20.190 | 0.001** |
| | II | 38 | 0.09 | 0.29 | | 0.071 | | |
| forum | I | 6 | 0.02 | 0.13 | 1 | 0.113 | 4.322 | 0.038* |
| | II | 12 | 0.04 | 0.20 | | 0.026 | | |
| co-drawing | I | 3 | 0.01 | 0.09 | 1 | 0.865 | 23.805 | 0.001** |
| | II | 23 | 0.08 | 0.27 | | 0.036 | | |
| flickr | I | 14 | 0.04 | 0.19 | 1 | 0.001 | 0.015 | 0.90 |
| | II | 11 | 0.04 | 0.19 | | 0.036 | | |
| youtube | I | 12 | 0.03 | 0.18 | 1 | 0.805 | 14.186 | 0.001** |
| | II | 29 | 0.1 | 0.30 | | 0.057 | | |

**p<0.001 *p<0.05 I – Case I (Spring 2007) II – Case II (Fall 2007)

The in depth Chi square analysis indicated that in Case I the aggregator-related affordances were mentioned significantly more frequently than expected ($\chi^2=6.846$, $df=1$, $p<0.01$). However, in Case II the affordances related with blog ($\chi^2=5.539$, $df=1$, $p<0.001$), chat ($\chi^2=1.496$, $df=1$, $p<0.001$), forum ($\chi^2=4.307$, $df=1$, $p=0.038$), social bookmarks ($\chi^2=7.645$, $df=1$, $p=0.006$), co-writing ($\chi^2=1.965$; $df=1$, $p<0.001$) and co-drawing tools ($\chi^2=2.306$, $df=1$, $p<0.001$) and Youtube social repository ($\chi^2=1.393$, $df=1$, $p>0.001$) were mentioned significantly more often than expected. This indicated, that in Case II, students perceived more learning affordances that were related with social software for collaboration. Difference in the higher perception of certain affordances related with collaborative tools in Case II compared with Case I might have been caused by various reasons. In their final postings about their progress at the course students expressed that they had previously had very little possibilities of working collaboratively in technologically aided environment, collaborative task was interesting and challenging for them, and they were satisfied with the new experience. Since at for them this learning course was also the first course where they initially met with other students, they presumably also tried to establish some community relationships using these collaboration tools.

The distribution of affordances between affordance types at two cases was compared as well. The comparison of different types of affordances used in Cases I and II is presented in Table 4. It appeared, that the significant differences in the perception of main learning affordance types in two cases occurred only with few affordance types. In comparison with the significant differences ($p<0.001$) that were found in the distribution of affordances between tools in two Cases (see Table 3), all detected differences appeared between affordance types appeared at lower significance level ($p<0.05$).

The Chi square analysis indicated that differences between cases occurred in the affordance types of 'managing the learning environment' ($\chi^2=6.506$, $df=1$, $p<0.01$), 'assembling the learning environment' ($\chi^2=5.44$, $df=1$, $p=0.020$) and 'reflecting' ($\chi^2=4.718$, $df=1$, $p=0.030$), which occurred significantly higher than expected in Case I. This might be explainable with the fact that the course was run first time, and also the facilitators learned during the course how

to manage such social software based course. Apparently, this novel self-managing aspect caught students' increased attention. The 'presenting' affordance type was found more frequent than expected ($\chi^2=4.912$, $df=1$, $p=0.027$) in Case II.

Table 4. ANOVA of the distribution of learning affordances between affordance types in Case I (N=381) and Case II (N=285)

| Affordance types | Case | N | Mean | StdDev | df | Mean square | F | Sig |
|------------------------------------|------|----|------|--------|----|-------------|-------|-------|
| assembling | I | 66 | 0.17 | 0.37 | 1 | 0.677 | 5.472 | 0.02* |
| | II | 31 | 0.11 | 0.31 | | 0.124 | | |
| managing | I | 17 | 0.04 | 0.20 | 1 | 0.190 | 6.550 | 0.01* |
| | II | 3 | 0.01 | 0.10 | | 0.029 | | |
| creating | I | 36 | 0.09 | 0.29 | 1 | 0.100 | 1.065 | 0.30 |
| | II | 34 | 0.12 | 0.32 | | 0.094 | | |
| reading | I | 14 | 0.04 | 0.18 | 1 | 0.004 | 0.130 | 0.71 |
| | II | 9 | 0.03 | 0.17 | | 0.033 | | |
| presenting | I | 35 | 0.09 | 0.28 | 1 | 0.502 | 4.934 | 0.03* |
| | II | 42 | 0.15 | 0.35 | | 0.102 | | |
| changing and adding | I | 17 | 0.04 | 0.20 | 1 | 0.212 | 3.770 | 0.053 |
| | II | 23 | 0.08 | 0.27 | | 0.056 | | |
| collaborating and communicating | I | 68 | 0.18 | 0.38 | 1 | 0.283 | 2.096 | 0.15 |
| | II | 39 | 0.14 | 0.34 | | 0.135 | | |
| sharing | I | 24 | 0.06 | 0.24 | 1 | 0.071 | 1.390 | 0.23 |
| | II | 12 | 0.04 | 0.20 | | 0.051 | | |
| exchanging | I | 6 | 0.02 | 0.12 | 1 | 0.013 | 0.660 | 0.41 |
| | II | 7 | 0.02 | 0.15 | | 0.019 | | |
| searching | I | 31 | 0.08 | 0.27 | 1 | 0.001 | 0.017 | 0.89 |
| | II | 24 | 0.08 | 0.27 | | 0.076 | | |
| filtering and mashing | I | 48 | 0.13 | 0.33 | 1 | 0.285 | 2.955 | 0.08 |
| | II | 24 | 0.08 | 0.27 | | 0.096 | | |
| collecting | I | 14 | 0.04 | 0.18 | 1 | 0.001 | 0.013 | 0.91 |
| | II | 10 | 0.04 | 0.18 | | 0.035 | | |
| storing | I | 15 | 0.04 | 0.19 | 1 | 0.155 | 3.113 | 0.08 |
| | II | 20 | 0.07 | 0.25 | | 0.050 | | |
| tagging | I | 16 | 0.04 | 0.20 | 1 | 0.032 | 0.909 | 0.34 |
| | II | 8 | 0.03 | 0.16 | | 0.035 | | |
| argumentation and reflecting | I | 41 | 0.11 | 0.31 | 1 | 0.375 | 4.737 | 0.03* |
| | II | 17 | 0.06 | 0.23 | | 0.079 | | |
| monitoring | I | 19 | 0.05 | 0.21 | 1 | 0.003 | 0.064 | 0.80 |
| | II | 13 | 0.05 | 0.20 | | 0.046 | | |
| give tasks supporting | I | 36 | 0.09 | 0.29 | 1 | 0.033 | 0.367 | 0.54 |
| | II | 31 | 0.11 | 0.31 | | 0.091 | | |
| asking giving and getting feedback | I | 29 | 0.08 | 0.26 | 1 | 0.139 | 1.715 | 0.19 |
| | II | 30 | 0.11 | 0.30 | | 0.081 | | |
| evaluating | I | 15 | 0.04 | 0.19 | 1 | 0.029 | 0.665 | 0.41 |
| | II | 15 | 0.05 | 0.22 | | 0.043 | | |

**p<0.001 *p<0.05 I – Case I (Spring 2007) II – Case II (Fall 2007)

In general it can be assumed that learners' perception of the most learning affordance types differed very little in Cases I and II. Mainly similar distribution of specific affordance types in Cases I and II indicated that the same kind and amount of affordances were perceived necessary in both cases for self-directed learning (Table 4). However, the same niche was actualized significantly differently with tools at Cases I and II (Table 3). This finding is in accordance with the theoretical proposition that learning spaces may emerge like repeated sets of affordances, which describe the learning niche for certain learning and teaching community. This means that in the learning design model the learning space needs to be conceptualized as a niche, composed of certain learning affordances, rather than

the fixed set of tools, similar for all learners. If following this principle, learners will be provided with the freedom of choosing personal tools for realizing the learning niche.

Using learning niche descriptions for cyclical development of course design

The niche descriptions can potentially serve as useful means for cyclical development of the courses. In biology, niches have been visualized by different means, for example the amplitude of using certain kind of niche gradients might be visualized. Learning niches can be defined by the frequency each learning affordance is perceived useful for the community when making use of the certain software among all other available or chosen tools. Thus, user-collected frequency data about each affordance type can be used to calculate to which extent each available tool in this community would be perceived useful for activating this affordance. The optimums for certain learning affordance types were calculated dividing the frequency of this affordance per certain software type to the total frequency of certain learning affordance type for all the software types. The results were plotted as the niche maps with wireframe contour figures of MS Excel (see Figure 1).

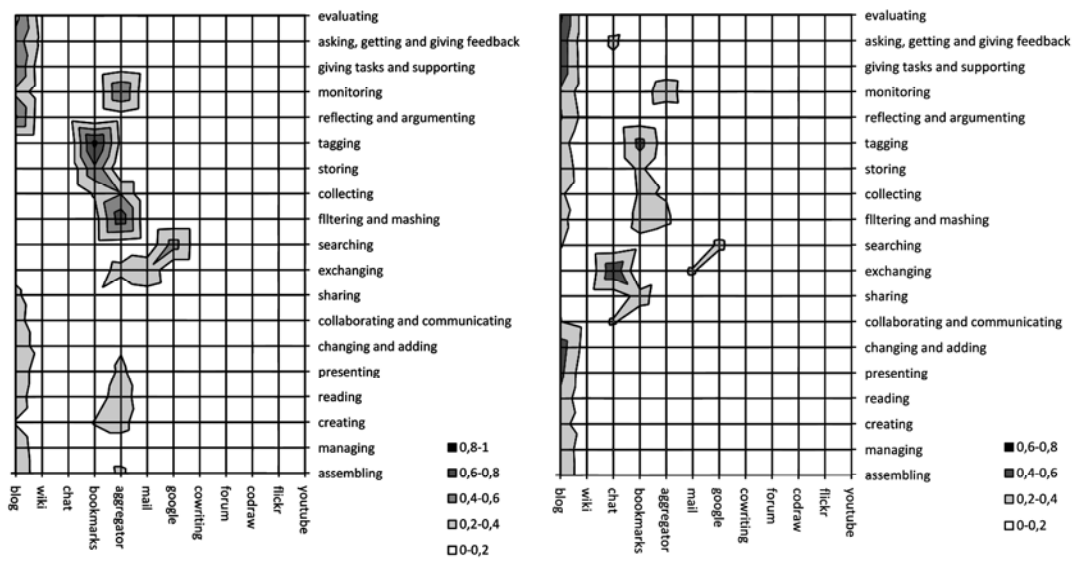


Figure 1. Realized niche landscapes of Case I (left), and Case II (right) presented with the contour lines representing gradient directions from 0-1

Figure 1 demonstrates the realized course niches with the use of certain type of tools in Cases I and II. The niche is plotted as the landscape where contour lines represent the niche gradients in respect to certain tools. The comparison of figures indicated that in Case II certain progress occurred and learners managed to perceive more affordances that are particular to social Web. This might have been caused by the increasing experience of course facilitators in presenting the software possibilities.

Certain differences between two cases served as a valuable feedback for the course developers to grasp the realized niches of the students. It appeared that in Case II students perceived blogs not only as their reflection places that are monitored, scaffolded and evaluated by facilitator and other students, but also noticed the sharing, tagging, filtering and mashing affordances. Thus, it may be assumed that in Case II facilitators were better able to draw students' attention to the new features, common specifically to social software, that blogs offer.

While the affordances of exchanging and sharing were perceived in relation to email in Case I, indicating to the habit of using email as the main tool in the course communication, in Case II chat and social bookmarking tools took over this role. This change in Case II towards using social software that enables new type of activities with information was seen as positive, indicating that students really started to carry out activities with social software tools.

In students' perception an aggregator had a more important role in Case I than in Case II. Students perceived that aggregator supported monitoring, presenting, reading, creating and assembling affordances in Case I, while in Case II only monitoring affordance prevailed. The decreasing significance of aggregator-related affordances was surprising, and pointed to the need to draw students' attention towards self-managing and assembling aspects of social bookmarking and aggregation tools in the next runs of the course.

Discussion

This article pointed to the need for the new learning design frameworks for self-directed learning with social software that were ecological. This learning design emphasizes the following aspects, which were developed and tested empirically.

Theoretically, in the self-directed learning process students should be promoted to use their own personal learning environments. Thus, the learning environment as a system of tools and resources cannot be ready when learning starts but has to evolve as part of learners' self-directed individual and collaborative action process in which facilitator has a guiding role. The applicability of emergent course design was tested at two cases. The dense methodological description introduces specific details of this approach, however, it presents only one possible way how social software could be used in the learner-centered manner. Therefore, in this paper it was attempted to give a general framework how to plan and control various emergent course designs.

To run emergent bottom-up courses, facilitators would need to establish some constraints and guidelines for planning the learning process. Rather than composing a list of optional course tools, resources and activities, an abstract learning space might be determined for the course design and made explicit to the learners. This article proposes that learners' perception of action potentialities of their personal and collaborative learning environments – learning affordances - could be dynamically collected in a bottom up manner during learners' public planning of their goals, visualization, and self-reflection of their learning activities and learning environments. Knowing these learning affordances and making the abstract learning space explicit for the learners and for the facilitator would permit: i) the individualized learner-specific integration of their goal-directed activities with other perceived components, resources and community activities in the environment; and ii) the reuse of the commonly perceived affordances for environmentally adaptive self-direction.

In this study the course for self-directed learning with social software and the ideas of an ecological learning design framework were simultaneously developed. Ideally the emergence of the course's learning space would consist of cycles of developing and monitoring the learning niches. Such dynamical monitoring and grounding of the mutually used learning affordances was possible and practiced during both courses. For this learners' schemes and reflective postings in their weblogs were used. However, the whole learning niche was not clearly visible for students in the course of action. The learning niche analyses of Case I and II were created after each course was over, and used mainly for evaluative purposes for planning the changes of the course. However, it is assumed that if some tools were available for learners and facilitator to visualize the niche with less analytical effort during the course of action, this might increase the use of affordances as niche gradients in adaptive shaping of self-directed learning.

Knowing the fundamental learning niche characteristics enables to develop particular list of suggested activities and plan appropriate instructions during the course. In this study it was found that students perceived many affordances that are related with planning, reflecting and evaluating personal learning in collaborative social software settings. In this paper only the list of these affordances was presented, however, potentially these affordances could be further used for activity design.

When planning participation at the courses and for choosing tools and resources for personal learning environments, self-directed students might need information of the affordances that a particular course community perceives in relation to certain tools. In this paper the factor analysis brought out that some types of social software might offer a unitary affordance perception possibility while others would evoke different types of affordances. It is assumed that, during the learning activity the latter software would serve as multifunctional for switching from one learning niche to another. We have not analyzed in this paper the particular differences between learning niches (eg. for individual or collaborative activities) that form the learning space, but there is evidence (Pata, in press) that such distinguishable niches appear within the general learning space.

One of the expectations of investigating the course learning space at consequent years was to see if the fundamental learning space for self-directed learning with social software was stabile and potentially replicable while students had a big freedom of using various tools. The ANOVA analyses demonstrated that while the use of affordances clustered by different types of social software differed significantly at Cases I and II, the affordances clustered by affordance types were used with similar frequency at both cases. This permits to conclude that the affordance-type based learning space description might be re-used in the course design as a guideline for students and the facilitator, for deciding which affordance types should be evoked at the course. Coupling this affordance-based learning space description with the descriptions of the affordances that certain community has activated with certain types of tools, and considering individual perception of affordances of the personal learning environment, enables learners to participate at joint course activities with their own tools.

Conclusions

This paper outlines the main principles of an ecological learning design model, which is suitable for supporting self-directed learning in social software-based Web systems. It demonstrates how to consider learners' actions and learning environment perception ecologically in the evolving learning design framework. It is envisioned that when applying such learning design frameworks, the recording and visualizing of the emerging affordances while coupling the activity patterns and learning environment resources in the communities must be under special attention. Affordances as connectors of goals, actions and environmental resources constitute a powerful carrier of an ecological knowledge in new Web systems – a driving force for dynamical changes in Web cultures and learning paradigms, and the guide to the optimal activities in learning spaces.

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APPENDIX 1. Affordances types of the self-directed learning niche with social software

Assembling: Assembling information, connecting information/data/artifacts, pulling feeds to the aggregator, community-wide assembling and monitoring of aggregated information, adding bookmarks to social repository, assembling a joint communication environment, creating connection points for group-work, relating weblogs with other mediating environments;

Managing: Self-managing the systems, student/facilitator can restrict/provide access, adding important information, creating time-tables and action plans, sending reminding notes into shared calendar, coordinating actions;

Creating: Co-writing, collaborative creation with other students; simultaneous creation with group members, teacher can look the created work, student develops the goal of the task, teacher evaluates the created work, creating learning materials, giving opinions to peer-students' creations, student chooses the tools to solve the task, learning from joint writing, using jointly created artifacts;

Reading: reading peer's weblogs, an interest-based reading of weblogs, searching images/videos/books while using information collected from blogs, tagging information found in weblogs, quick view to publicly published notes, teacher/other student can read and comment students' published work, reading tasks at weblog;

Presenting: Hanging works in internet, presenting information to the students, publishing artifacts/homework/ideas in blog, offering personal RSS feed, presenting artifacts community-wise, initiating topics in blog, publishing news into shared aggregator, posting personally interesting information, changing the color of notes to make them distinguishable, making information feeds to demonstrate results;

Changing and adding: student can change and add data, student/facilitator can change texts and make corrections, student can make corrections after feedback, student can add his own sub-topic, student have access to editing, students/facilitator can adding figures, images, sounds, slides and RSS feeds to the community resources;

Collaborating and communicating: Working jointly, communication with team members, viewing bookmarks collaboratively for learning in group; coordinating the information among the group of students, community-based viewing/listening of artifacts, learning from shared results, trusting each other, synchronizing and harmonizing work, individual communication with the community-members, calling new members to collaboration, co-writing simultaneously complementing texts and images;

Sharing: Sharing data/information/materials with interested counterparts/community, taking into use the artifacts of shared learning activity, sharing personal feeds, using shared resources, sharing with the use of tag-clouds;

Exchanging: exchanging materials/experiences/knowledge with other learners, quick and inexpensive exchange of information, exchanging information privately;

Searching: learners are searching ideas, searching information for learning from different sources, searching without leaving personal learning environment, searching by keywords;

Filtering and mashing: filtrating information, pulling RSS feeds, RSS feeds go automatically from various places to aggregator, filtrating information by interest/by tag, mashing RSS feeds, analyzing RSS feeds, connecting information and artifacts, community members can individually add feeds to shared resources;

Collecting: facilitator/learner collects data, collecting data from peer students, collecting a personal information store, collecting the results from the group activity, community members can collect individually artifacts/links for the community;

Storing: storing/saving data, information/artifacts/results/homework, social bookmarking, storing in social repository, storing and providing tags;

Tagging: Choosing bookmarks by searching tags, marking important information, adding tags to texts/important information/posts/books, saving bookmarks with tags, social aggregation of information with tags, finding similar people by their tag-clouds, remembering important information with tags, sharing with the use of tag-clouds, initiating new tags, access to information by tags, social retrieval of information by tags;

Reflecting and arguments: reflecting on artifacts in the weblog, self-reflection; self-analysis, relating community reflection with facilitator-reflection, argumentation, analyzing information feeds, making homework/problem-based work, discussing tasks and making decisions, keeping personal learning contracts;

Monitoring: the facilitator/students can monitor the process of solving the tasks, facilitator/students can monitor different teams, community-wide monitoring of aggregated information, collaborative monitoring the feeds/co-students, community can monitor teachers' RSS feed, monitoring comment-feeds from feedback, monitoring collection of community resources (eg. bookmarks, slides);

Giving tasks and supporting: Facilitator/student is giving tasks/posting homework and supporting students; giving enthusiasm, supporting collaboration, promoting team-formation;

Asking and giving-getting feedback: coordinating understandings/information with students, asking from the community/peer student/facilitator, commenting/giving feedback to peer's work, getting feedback, getting information from the users;

Evaluating: self-evaluation, evaluation of students' new knowledge, recognizing students, evaluating feeds, evaluating managing the learning environment and the use of resources, evaluating the affordances of the environment, peer- and facilitator-assessment, providing evaluation criteria.

Visualisation of interaction footprints for engagement in online communities

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ABSTRACT

Contextualised and ubiquitous learning are relatively new research areas that combine the latest developments in ubiquitous and context aware computing with educational approaches in order to provide structure to more situated and context aware learning. The majority of recent activities in contextualised and ubiquitous learning focus on mobile scenarios, with location as the primary contextual dimension. However, the meaning of context aware learner support is not limited to location based solutions, as it is highlighted by the educational paradigms of situated learning and communities of practice. This paper analyses learner participation as a contextual dimension of adapting graphical indicators of interaction data for engaging and motivating learners in participating and contributing to an open community. The analysis is based on interaction data and interviews with participants in a nine week lasting design study, during which we compared the effect of two indicators on the engagement of the participants in the group activities. The trend of study results supports the presumption that the learners' perception of their activity visualisations is context dependent. We found that more engaging visualisation polarised the participants in this group: while contributing participants were attracted to contribute more to the community, non-contributing participants were distracted by the same visualisation.

Keywords

Learner support, Self-directed learning, Information visualisation, Context-awareness, Evaluation

Introduction

Contextualised and ubiquitous learning are relatively new research areas that combine the latest developments in ubiquitous and context aware computing with educational approaches in order to provide new forms of access and support for situated learning. The majority of activities in contextualised and ubiquitous learning focus on mobile scenarios, in order to identify the relation between educational paradigms and new classes of mobile applications and devices (Naismith, Lonsdale, Vavoula, & Sharples, 2004). However, the meaning of context aware learner support is not limited to mobile learning scenarios by default. The educational paradigms of situated learning and communities of practice (Lave & Wenger, 1991) highlight the need for contextualisation of informal learning, particularly where learning activities are related to the workplace. In these scenarios learning processes are often unstructured, unguided, and sometimes even unintended.

Our previous work analysed the potential of contextualised visualisations of interaction data for supporting informal learning (Glahn, Specht, & Koper, 2008). We call such visualisations *action indicators*. They are called *smart indicators*, if the visualisation follows rule-based adaptation strategies (Glahn, Specht, & Koper, 2007; Glahn, Specht, & Koper, 2008). Such indicators may help actors to organise, orientate, and navigate through environments as well as reflecting on their actions by providing relevant contextual information for performing learning tasks, informally.

The purpose of our research is to identify variables and conditions for selecting and adapting visualisations of “interaction footprints” (Wexelblat & Maes, 1999) in order to provide context sensitive learner support in informal learning. Such learning usually takes place in unstructured environments, where *unstructured* refers to the lack of pre-defined roles and instructional designs. In these environments learners interact at different expertise and activity levels in changing or implicit roles. The footprints of user interactions can be used to determine the context of a learner (Zimmermann, Specht, & Lorenz, 2005) by defining rules for the boundaries of each context.

In order to evaluate the benefits of indicators for learning processes, we proposed an adaptation strategy for visualizing action information on team.sSpace (Glahn, Specht, & Koper, 2007). It was necessary to evaluate the indicators of the adaptation strategy regarding their supportive effects and their contextual boundaries, because the design of the adaptation strategy is based on basic presumptions that were sound from the perspective of prior research. But could not be sufficiently grounded on empirical evidence. Therefore, this study is a qualitative exploration of the underlying design principles of contextualised learner support and focuses on the presumptions

made for the adaptation strategy. We analyse the contextual boundaries regarding the level of learner participation and if the proposed indicators are suitable for engaging learners in participating and contributing to a community.

The following sections of this paper report on this evaluation. The next section discusses the conceptual background of our research. It compares and links psychological models and educational concepts with the findings of research on technology enhanced learning. The third section links the concepts to identify the gap for further research. This gap is used to set the question for research. The fourth section describes the setting of the evaluation. In this section the teamSpace system is introduced and the set-up of the indicators is explained. The fifth section links our research question and the setting towards the four hypotheses that were tested by our study. The method of analysing the setting regarding the given hypotheses is given in section six. Section seven reports the results of the automatically collected interaction footprints and the results of the interviews with participants. Finally, section eight discusses the results regarding the hypotheses and the implications for our research question.

Background

Butler & Winne (1995) reported that environmental responses on actions are crucial to learners for controlling and structuring their learning process. According to the authors, one result of triggered cognitive processes is the learner's decision whether and how to proceed with their interactions with an environment. This implies that the responses to the learners' activities influence the quality, pace, and duration of their future learning activities, which includes also the option of dropping out. Based on prior findings the authors introduced a system model of the cognitive processes that are crucial to self-regulated learning. The model focuses on how learners assess, relate and integrate external information with their prior knowledge and experiences to control their actions, tactics, and strategies of interaction with the environment. In this sense this is an evolutionary model, because it includes the learners' self-regulating capabilities to the responses given by an environment. The learners' actions and reactions are connected to their past experiences and are integrated into their knowledge. This integration is a *knowledge construction* process, in which the learners' prior knowledge is constantly assessed against the effects of their actions in an environment. Alas, the learners' experiences are evolving, and the resulting experiences influence the interpretation of external responses on a learner's actions. This is a well known effect in workplace related competence development (Wenger 1998; Elkær, Høyrup, & Pedersen, 2007; Chisholm, Spannring, & Mitterhofer, 2007).

There are two limitations with this model with respect to contextualised learner support. First, the model focuses mainly on the cognitive processes of a learner. Second, the model does not include concepts to explain the motivation of learners depending on the contexts of their actions; i.e. the model focuses entirely on the actions of a learner and how responses on this action lead to other actions. The emphasis of the cognitive processes in this model, leaves the context of a learner's actions abstract concepts of prior experiences or to the external setting. Therefore, the model helps to understand the cognitive processes underlying self-regulated activities, but provides little information about how to support such processes in varying contexts.

Lave & Wenger (1991) introduced the concept of *situated learning*. This concept reflects the social dimension of learning. Situated learning emphasizes that learning is always embedded and contextualized by the social practices of a community. The background for this research is mainly informal and non-formal learning as it can be found in the professions. In their later work the authors independently highlighted several dimensions and factors of contextualisation in learning (Lave, 1993) and contextual support for learning (Wenger, 1998).

Lave (1993) identified that the problem of context in learning has to focus on the relationships between local practices that contextualize the ways people act together, both in and across contexts. From this perspective is context constructed by social activity. At the same time the *context* limits the possible actions and the perception of their effects. This means that learning cannot be reduced to a set of contextual learning *events*, but requires tight coupling to the social practices in which learning *processes* are situated.

From an analysis of field studies Lave (1993) deduces six dimensions that characterise the context of learning: *process, group or peers, event or situation, participation, concepts, and organisation or culture*. In a later study, Wenger (1998) extracted 13 factors of supporting situated learning processes. These factors affect the learning process by allowing the development of the learners' identity and meaning regarding the social practices of their

learning contexts. Table 1 shows the relation between Lave's (1993) contextual dimension and Wenger's (1998) context factors.

For our research Lave's (1993) and Wenger's (1998) notion of meaning is important. In our understanding of their work *meaning* is not necessarily coupled to predefined learning objectives (Lave, 1993), but is developed through the social interactions of the learners (Lave, 1993; Wenger, 1998). In other words, what is meaningful to the learners and what they learn varies in different contexts.

Table 1 shows the relation between Lave's (1993) high level context dimensions and Wenger's (1998) factors for supporting situated learning. This allows us to identify for a context dimension, which types of interpretations of the learning processes can be expected. In this study we focus at the level of participation as the primary context dimension. Therefore, we would expect that meaningful experiences will be related to the following factors: *presence, interaction, involvement, personal identity, communal identity, boundaries, and community building*.

Compared to the model of Butler & Winne (1995) the contextual dimension and factors provided by Lave (1993) and Wenger (1998) help to argue design decisions for situated learning environments. The downsides of their concepts are that they provide the outer boundaries for technical support, but no guidelines for system design. However, the two theories of Butler & Winne (1995) and of Lave & Wenger (1991) are not mutually exclusive: while the Butler & Winne's model allows us to understand reflection and motivation as *cognitive processes* that connected to social interaction, Lave and Wenger's work helps us to identify contextual factors that structure *social processes*. Therefore we choose both approaches as the theoretical framing on the educational psychology side of our research.

The idea of using information about a user's actions to provide meaningful information in return is not new from a technical perspective (Kobsa, 2001). In research on user modelling questions on how to track, store, and analyse user interactions in order to adapt or to personalise interactive systems are key issues since applications in Intelligent Tutoring Systems (ITS). Important components for contextualized support can be separated into the four levels *action tracking, action analysis and assessment, personalisation/adaptation, and system response*. The four levels have been generalised by Zimmermann, Specht, & Lorenz (2005) into a system-architecture for context aware systems. From the systemic modelling stance of the earlier discussion, this architecture can be seen as a counter part to the cognitive processes of Butler & Winne's (1995) model.

Table 1: contextual dimensions and contextual factor alignment

| Lave, 1993 → | Process | Peers | Event | Participation | Concept | World |
|--------------------|---------|-------|-------|---------------|---------|-------|
| Wenger, 1998 ↓ | | | | | | |
| Presence | | X | X | X | | |
| Rhythm | X | | X | | | |
| Interaction | | X | | X | | |
| Involvement | | | | X | | |
| Value | | X | | | X | X |
| Connections | | X | | | X | X |
| Personal Identity | | | X | | | |
| Communal Identity | | X | | X | | |
| Relations | | X | | | | |
| Boundaries | | X | | X | | |
| Integration | X | X | | | | |
| Community Building | X | X | | X | | |

Wexelblat & Maes (1999) showed that traces of user actions – so called interaction footprints – can be used to support the navigation through unknown information, which is the underlying concept for social recommendation in technologically enhanced learning (Drachsler, Hummel, & Koper, 2008). Farzan & Brusilovsky (2004) analysed different kinds of interaction footprints in order to improve the quality of adaptive annotations. Others (Dron, Boyne, & Mitchell, 2001; Erickson & Kellogg, 2003; Kreijns, 2004) utilised interaction footprints for providing learner support in informal learning, without directly recommending contents or actions to the users.

Erickson & Kellogg (2003) provide some examples of supportive visualisations of interaction footprints with regard to social information in online spaces such as discussion forums. Such *social proxies* – as the authors call such visualisations – are “minimalist graphical representations that portray socially salient aspects of an online situation” (Erickson & Kellogg, 2003). One effect of presenting social proximity without recommending learning activities or navigational behaviour has been reported as *waylay*. The concept refers to how a user monitors the indicators for another persons' activities and then initiates contact (Erickson & Kellogg, 2003). Similar to this concept is *stigmergy* (Dron, Boyne, & Mitchell, 2001). While waylay refers to virtual landmarks which are used by users to structure and plan their social activities, stigmergy refers to pathways of activities that emerge through collaborative activities.

Kreijns (2004) identified an effect related to group awareness indicators on distributed activities of peer users, which the author calls *social affordance*. Social affordance refers to information that stimulates activities that are aligned to the social practice within a collaborative environment. Different to social proxies the group awareness indicators that were used by Kreijns (2004) provide only information about the recent activity of peer users, but not about the relations between the activities or the users involved. Social affordances rely on meaningful responses to a user's actions and on the users' ability to relate the responses to their actions. (Kreijns, 2004).

All three concepts – waylay, stigmergy, and social affordance – and the related approaches can be explained by the model of Butler & Winne (1995). They all provide external responses on the learners' actions, which can be used for self-assessment and self-regulation. It is also possible to associate each approach to one of the contextual dimensions of Lave (1993) and Wenger (1998). However, similar to other visualisations of interaction footprints, these approaches were not analysed regarding their situated effects (Glahn, Specht, & Koper, 2008).

Motivation for research

Although there is some evidence that context is a critical factor for learning, the related technology enhanced learning research has not analysed if learner support is context dependent. Therefore, it is not possible to infer from prior research how contextualised visualisations influence engagement and reflection in informal learning. This gap in research leads us directly to the motivation for research of this paper: *what is the effect of interaction footprint visualisations in different contexts?*

Regarding this research question, the main research interest is if waylay and social affordance are dependent to the participation level of users of online communities. Therefore, we chose the participation as the contextual dimension. For evaluating the initial adaptation strategy the levels of participation are distinguished as contributing and not-contributing. Regarding the effect of the visualisation, we are interested in how the indicator affects the engagement of the users in using team.sSpace (Glahn, Specht, & Koper, 2007). Hence, we focused our research to the following question: *what are the effects of interaction footprint indicators on the engagement of users within a community information portal, depending on their level of participation?*

Setting

team.sSpace

To answer this question we used the team.sSpace system (Glahn, Specht, & Koper, 2007) in a nine weeks lasting design study within our department. team.sSpace is a group information portal for online communities of practice, which jointly form a larger “learning network” (Koper et al., 2005). Each community in team.sSpace is built around the topics and the interests of their participants. The participation in team.sSpace is open and users can register and set

their personal information as they would do as if they were using any other social-software platform on the web. Figure 1 shows a typical view of team.sSpace for an authenticated user.



Figure 1: team.sSpace screen for an authenticated user

The information presented in team.sSpace is aggregated from the participants' weblogs and social bookmarks from delicious.com. The system aggregates the information from different services using information feeds. This allows the participants to use their tools while contributing and sharing information. In order to participate, the participants had to register and add the URLs of their personal services used to their user profile in team.sSpace. After registering the preferred service URLs, team.sSpace starts collecting information from these services. team.sSpace limits the aggregated information to public resources that have been "tagged" by the participants. Private or untagged resources are ignored.

The front-end of team.sSpace presents the aggregated information in three columns. The left column displays the latest social bookmarks, the middle column shows the latest weblog contributions, and the right column shows the tag cloud of the community. The separation of different contribution types is based on the different pace of the two information streams. While social bookmarks are frequently added, writing weblog entries requires more effort. If both resource types would be presented as a single stream of information, weblog contributions will hardly receive any visibility in the community. While the first two columns show the recent activities of the community members, the tag cloud displays those tags that are shared by them and provides an impression of the community's global interests. Besides the presentation of community interests, the tag cloud serves also as a navigation tool, through which users can apply filters to the other columns' content.

A small information indicator extends the basic functions. The visualisation of the indicator displays the recent activity of the current user. The information shown is based on the user's recent contributions, the visits to the portal, the number of filters that were applied, as well as the contributions, which were accessed by the user through the portal. This indicator takes up the concepts of social proximity (Erickson, 2008) and group awareness (Kreijns, 2004; Kreijns & Kirschner, 2002).

Setting of the study

Two information indicators were provided for analysing the influence of context on the perception of interaction footprint visualisations. Each participant was randomly assigned to one of the indicators during registration time. Apart from the different indicators all participants had access to the same instance of team.sPace.

The first indicator was an activity counter. It displayed the interaction footprints of a participant. Each action of a participant is counted; and all actions have the same impact on the visualisation. The activity is visualised in a horizontal raster bar-chart (see Figure 2). This chart does not grow homogeneously with each action, but a participant has to “earn” each field with a pre-defined number of actions. With an increasing number of activated fields more actions are required for a new field, similar to the logarithmic activity scale that has been used by Kreijns (2004).

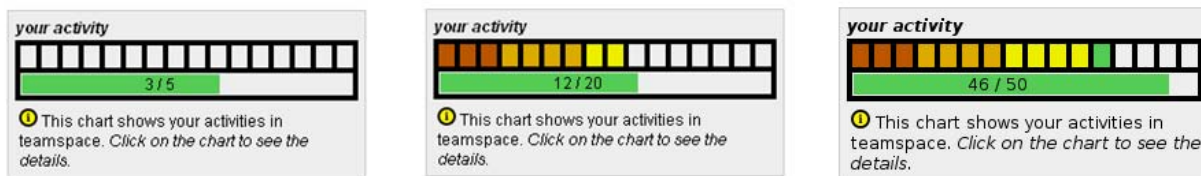


Figure 2: the activity counter after 3, 72, and 196 actions

The second indicator is a performance chart. This indicator is different to the first indicator in three ways. Firstly, it values the different activities with a factor that is multiplied to the user's activity points for that activity. This means that the activities have a different impact on the activity of the participant. For example an entry on a weblog is worth ten points, while selecting a link is only worth a single point. Secondly, the activity is not displayed in absolute terms, but relative to the activity of the most active user in the group. Finally, the indicator integrates a second bar, which charts the same information for the average participant of the community. The performance indicator is shown in Figure 3.

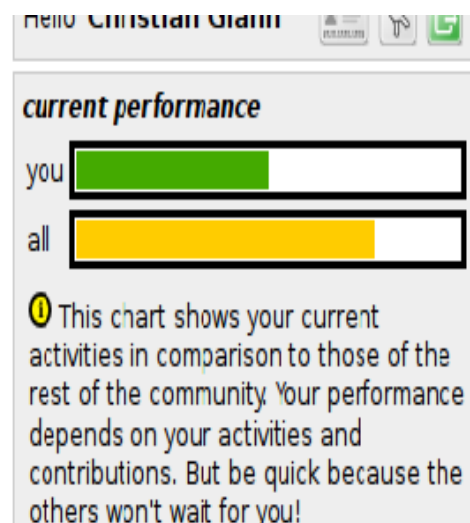


Figure 3: the performance indicator in action

Both indicators have a built in time constraint. The displayed information presents only the activity of the last seven days. This forbids users to pile-up actions and keeping their status while being inactive. Furthermore, both indicators provide the users detailed information of the underlying data. The users can access the details by clicking on the indicator. This action opens a small window, that shows the sources and the values in detail, which were visualised by the indicator. This assures that the users know what is displayed by the indicator.

Research questions

The design study intended to analyse visualising interaction footprints in relation to engagement and motivation at different stages of the learning process. Based on our previous considerations on self-regulated learning and context adaptation in the background section of this article, we formulate four research questions for this study.

1. Is the activity counter stimulating the engagement of non-contributing participants?
2. Will contributing participants ignore the activity counter after an initial phase of using team.sPace?
3. Does the performance indicator stimulate engagement and motivation in participating in the environment for contributing participants?
4. Is the performance indicator distracting for non-contributing participants?

The four research questions refer to the adaptation strategy, which has been previously proposed (Glahn, Specht, & Koper, 2007). This adaptation strategy argues that non-contributing participants should receive information about their actions on team.sPace in a way that is not competitive, while contributing participants receive information how they relate to others in the community. The purpose of this separation was to allow non-contributing participants to build relations to the community and to start contributing, without being distracted by strong performing participants.

Method

In order to come as close to the learning processes within a community of practice, the study has been conducted with the participation of selected researchers of our department. The group of scientific “knowledge workers” was selected to identify the design principles for supporting incidental learning processes in collaborative information organisation. The invited participants were selected affording to the similarity of their research topics, while previously these persons were not collaborating intensively with each other. All researchers in this group have a joint research interest of supporting lifelong competence development through web-based technologies. This selection has been made to achieve personal benefits for the information sharing by using team.sPace. Prior to this study the group used neither an integrated environment for sharing web-resources and weblogs nor similar tools for other types of resources.

14 persons volunteered in the team.sPace study of a period of nine weeks. During this period the participants should set team.sPace as the starting page of their web browser. For participating in the study, the participants had to register on the team.sPace website. During the registration, the participants were automatically assigned to one of the indicators. In order to guarantee to have about the same number of participants in each group, the selection algorithm assigned the participants alternating into the two groups.

Once registered the participants were able to authenticate to the system. The indicators were only available to authenticated users. During the observation period all actions of authenticated visitors were stored in a database. This action logging was used to aggregate the information for the indicators, as well as for the analysis of the user activities after the observation period. The recorded information included the accesses of the team.sPace website (visits), the access of resources (reading actions), filtering using tags in the tag cloud, social bookmarking, and weblog contributions. Because bookmarking and contributing weblogs were actions that were performed not within team.sPace, contributing participants could be active, even without visiting team.sPace directly.

Regarding the research questions the visits to the portal are important, because the related actions are directly linked to the visibility of the indicator. In terms of the interaction footprints recorded by team.sPace, engagement is translated as *more actions per visit at the system’s portal*. The other actions can be considered as indicators for the engagement of the participants. Therefore, we analysed the relation of the visits with the other actions.

For getting also a qualitative impression of the participants' experience we selected 6 participants, who were interviewed individually in a face-to-face meeting. We interviewed three participants of each group. In each group one participant contributed both bookmarks and weblogs to the community, one contributed only bookmarks, and one did not contribute at all. We selected the interview partners according to the frequency of using the system, according to their user type, and according to the treatment that they have received. All interviews were semi-structured and lasted between 20 and 30 minutes. During the interview we asked the participants to reflect about their use of team.sPace, about the parts of the system, which they liked and disliked, and about their impression of the indicator that was available to them.

Results

Of the 14 persons who registered themselves to team.sPace 7 participants were assigned to the performance indicator and 7 were assigned to the activity indicator. Five participants registered their research weblog in team.sPace; 8 participants registered their nick name for delicious.com. All participants who contributed their weblogs also contributed their delicious.com bookmarks.

Out of the 14 participants 4 stopped using the system directly after registration, of these participants 1 was assigned to the performance indicator. Another 2 participants were excluded from the evaluation, because they registered and defined the contributing services, but never visited the system afterwards. After this cleaning of participant information, 4 participants were assigned to the performance chart and 4 participants had access to the activity counter.

The contributing participants posted 549 bookmarks and 48 weblog entries over the three month period of the study. During this period the team.sPace portal has been visited 232 times by the participants. The participants followed 153 times a link to a contribution and used 140 times a tag of the tag cloud to filter the information on team.sPace.

Interaction footprints

Due to the small number of participants, the data from the user tracking is descriptive. It is used to highlight some trends that were observed during the study. However, these trends can only be read within the context of the interviews that are discussed later in this paper. This is relevant because we argue based on the grounds of qualitative data, drawn from the user tracking that is presented below.

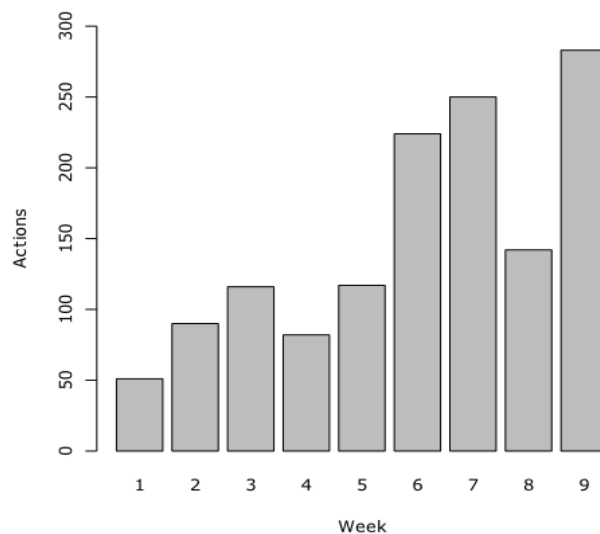


Figure 4: weekly user activity

When analysing the activities over time, it shows that the number of activities is increasing throughout the observation period (see Figure 4). If the actions are separated with respect to the groups that used the different indicators, it is remarkable that the majority of the actions has been performed by the group who was assigned to the performance chart, while the participants in the group that used the action counter was constantly less active during the same observation period (see Figure 5).

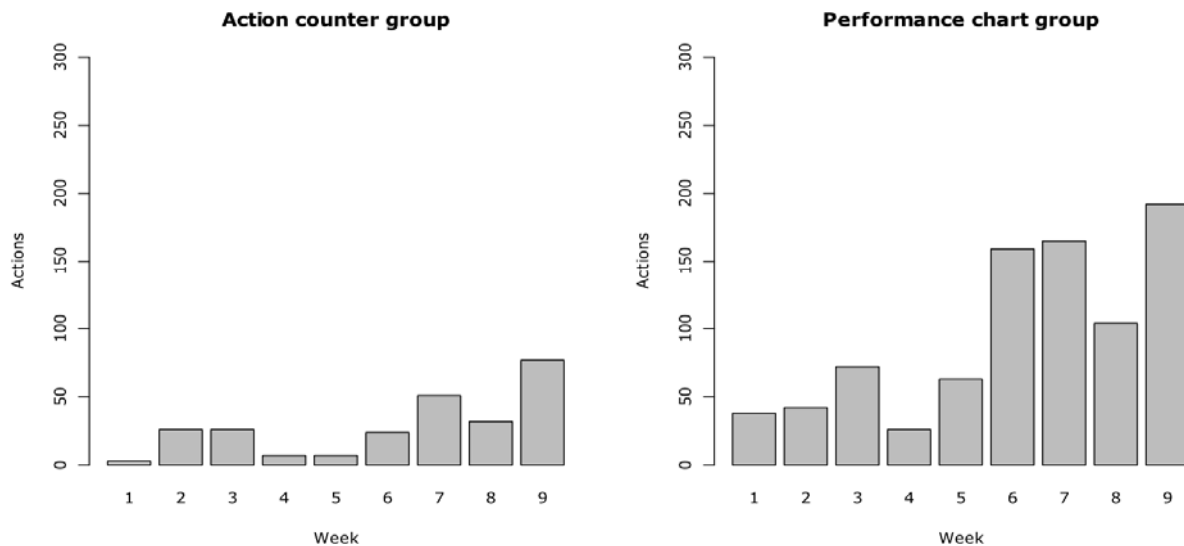


Figure 5: absolute weekly activity by indicator group, excluding visits

Given to this difference in activity, we were interested if this difference can also be observed with respect to visits on the portal. Interestingly, similar visiting patterns of the team.sSpace portal were found for both groups (see Figure 6). In other words, the participants of both groups used team.sSpace in a comparable way, regardless to which indicator they were assigned to. Also the visits appear to be unrelated to the activity of each group. For the participants who were assigned to the performance chart we found, that the increasing activity was entirely caused by the contributing participants of that group.

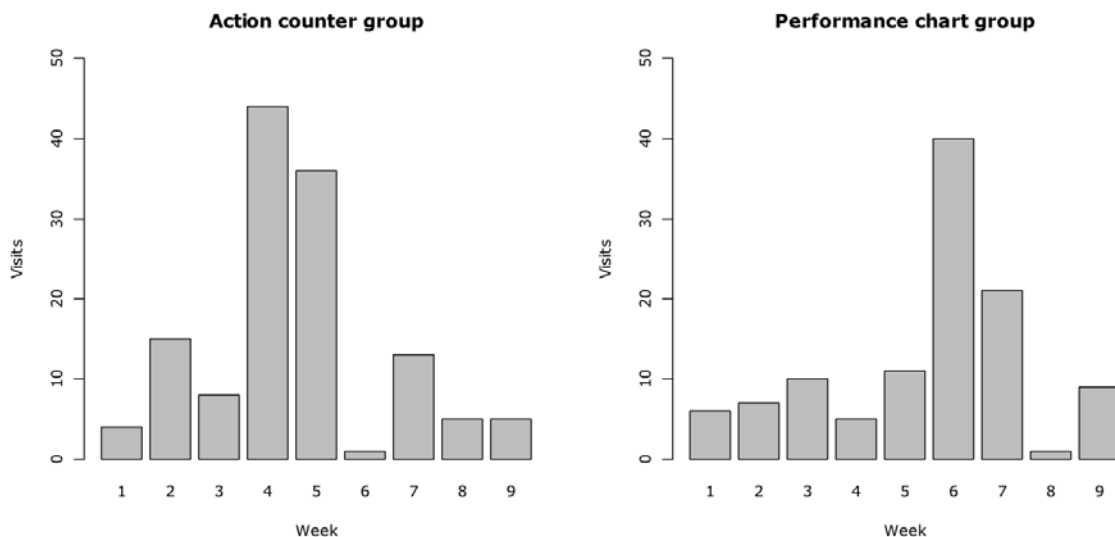


Figure 6: comparison of the absolute weekly visits by indicator group

Interviews

After the observation period, we selected six participants for interviews. Each interview partner was asked the same three questions that are listed in the method section above.

All interviewed participants replied on the first question about their general use of the system, that they frequently visited the portal, but they admitted that they did not use it as a start-up page of their browser. Instead they visited the page when it suited their working schedule. In these cases the participants checked what the other participants were bookmarking or posting on their weblogs. Nevertheless, they followed links only, if its abstract was interesting.

The interviewed participants reported that they liked the content organisation of team.sSpace for providing a quick overview of the topics the other group members were dealing with. The participants that were contributing social bookmarks and weblogs reported that through team.sSpace they started to estimate features of the external systems that they used prior to the study, already. An example of such experiences was the ability to comment bookmarks in delicious.com. Although adding notes and comments to bookmarks is an integral feature of all bookmarking systems, it is rarely used by default. However, in a group context, the comments can be used to highlight special features of a URL that is relevant to the community. Another example was provided by two participants: they reported that they learned about the value of social bookmarking when it is used within a group. One participant mentioned realising this as a surprise, because the participant used delicious.com for some time before the launch of team.sSpace.

With regard to the general use of the system, the participants who received the performance indicator were also focussing more consciously on the quality and quantity of the contributions of the other participants. One contributing participant was complaining about link “stealing”, when others bookmarked links that were previously posted by that participant on team.sSpace and – from the perspective of that participant – received performance points for that. The other contributing participant was contributing only social bookmarks and mentioned that the “bloggers” were “ruining” the performance by posting three or four postings almost simultaneously.

For the participants from the activity indicator group none of the interviewed contributors mentioned their recognition of such dynamics on team.sSpace during the interviews. However, the participants of this group reflected more about their experiences with the usability and the interface functions of team.sSpace.

All interviewed participants reported that they disliked the content browsing feature of team.sSpace. They found the collaborative tag cloud little helpful to find the contents they were looking for. One participant reported that it was not able to find a contribution via the tag cloud, although the participant remembered that the entry was on team.sSpace. The participants would have also liked to see the tags that were related to an entry. Furthermore, the participants were requesting a peer information feature, which provides a link to the participant's weblog, a link to the bookmarks on delicious.com, user based content filtering, or the tags that were used by another participant. Finally, the authentication procedure was not well received by the participants.

Regarding the question, how the participants experienced the indicators that were displayed to them, the two groups responded very differently. Those participants, who saw the activity indicator, responded that they checked their indicator at the beginning of the observation, and used it for finding out how the indicator responds to which interactions. Two within this group even “admitted” that they “tricked” the system to gain more points. However, for all three participants of this group the indicator lost its attraction after a while and the all three participants used team.sSpace mainly as a working group news portal, and in case of the contributors they contributed at their own pace. The participant, who was contributing bookmarks and weblog entries, stated that the indicator was “irrelevant for visiting” the portal.

The group who received the performance indicator answered differently. All three participants reported similar to the first group that they were playing around with the system in order to get familiar with the impact of their activities on the indicator at the beginning of the observation period. Because the underlying aggregator weights the different activities, it is more challenging for non-contributors to keep their performance up with the group. The non-contributing participant of this group reported this experience as “frustrating”, because the “bloggers” and “taggers” get all the points while the own activity chart hardly took off. In this particular case this frustration lead to a counter reaction: the participant created a new delicious.com account and posted a few links in order to see their impact on the performance. After the short reaction phase the participant did not contribute any other resources.

The contributing participants perceived the performance indicator more positive and connected it to the challenge of keeping up and outperform the community. In the interview both participants even asked if the indicator was displaying random information, because sometimes they estimated their performance better than what the indicator displayed. Nevertheless, both participants managed to become superior to the group and gain a maximum peek on the chart. According to the participants, this was very satisfying. The participant who contributed only bookmarks via delicious.com made this even a personal objective, which was reported as “pretty challenging” because of the random “waves” of weblog postings. Both participants reported that they followed the dynamics of the contributions carefully, as they related them to their impact on the performance indicator. Besides this generally positive connotation, both participants also mentioned that while they were “under performing” the indicator was a constant reminder. The participant who contributed both, bookmarks and weblog entries, reported “high pressure” in those cases when the personal performance chart was dropping and there was no time for new contributions due to other obligations.

Discussion

The results of the observation provide some insights regarding the research questions for the design of using visualisation of interaction footprints for learner support. With this regard, the combination of the analysis of interaction footprints and the results of the interviews allow us to indicate a trend. This trend is related on the different effects of the two indicators on the engagement of the different groups that was reported in the interviews. For initial validation of our research questions, the interviews need also to be confirmed by the interaction footprints of the participants.

The results do not allow to answer the research questions 1 and 4, because in both cases we were not able to attract enough participants. In case of question 4 the interview with a non-contributing participant in the performance chart group suggest that this question might get positively answered with a larger group of participants. A similar suggestion cannot be made for research question 1.

While both groups were initially attracted by understanding the relation between their activities and the visualisation of the indicator, after the initial phase of using the system the participants using the activity counter were less engaged with the group. Instead their responses focussed more on the general functions and usability of team.sSpace. Particularly the responses from the contributing participants support the second research question.

The responses of participants from the performance indicator group had a greater emphasis on recognising the group dynamics with a strong relation to valuing mechanisms of their activities related to team.sSpace. With that regard, the responses of the contributing participants are in line with the expectation of research question 3.

The interaction footprints confirm our conclusions to some extend. Particularly, by relating the visits and the overall activity of the participants, the interviews are in line with the research questions 3 and 4. The presumption was that contributing participants will be more engaged in contributing to the community if they are exposed to the performance chart. I.e., they should perform more actions per visit than other participants of team.sSpace. This is supported by the interaction footprints of the participants as Figure 7 illustrates.

Figure 7 shows the relation of visits to team.sSpace and all other actions per participant. This diagram shows that all three contributors of the performance chart group performed relatively more actions than the three contributors who had access to the action counter.

The findings are in line with the research questions 2 and 3 by the interviews and the interaction footprints suggests that the *social affordance* of interaction visualisations is sensitive to the level of *participation*. Although confidence provided by the data of our study is limited, the finding is important for our research in two ways. Firstly, *participation* is suggested as a contextual dimension, as it was initially proposed by Lave (1993). Secondly, within their limitations the findings indicate that providing a standard visualisation of interaction footprints to all users, does not meet the needs of all users in the same way. The effects might be positive for some, but this is not guaranteed for all participants.

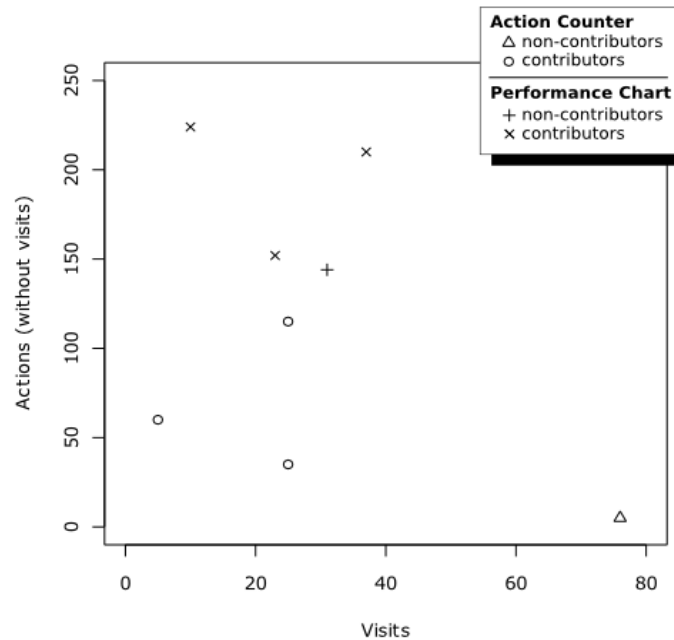


Figure 7: visit to action per participant relation

As the relations between context dimensions and factors of Lave (1993) and Wenger (1998) predicted, our findings suggest that the participants in the performance chart group were more sensitive towards the social dynamics and topics within team.sPace. The reports are interesting because the participants did not spend more effort in studying the contents on team.sPace. This might be a side effect of the *playing the system* that has been reported by the participants of the performance chart group. Such playing appears to have positive effect on the participants' reflection on contents and social dynamics. This finding is relevant for supporting self-directed learning for two reasons: firstly, the participants reflected more on their social context and contextualized their activities to the community; secondly, the indicator itself contains no content related information and provides only limited information about the social dynamics. We relate this effect to the presence of the indicator, because all other information was the same for all participants in this study. Future research will have to focus on this effect more thoroughly.

Conclusions

In this paper we analysed if two different visualisations of interaction footprints have different effects on the engagement of participants in an online community portal. The goal of this study research was to identify variables and conditions for selecting and adapting visualisations of interaction footprints in order to facilitate context sensitive learner support in informal learning. For this purpose the visualisations were embedded in a setting of collaborative information management. This setting was in use for nine weeks. To understand the effects on the different user groups, we analysed the interaction footprints of the participants and selected participants were interviewed about their experiences with the system.

We compared the results of the user actions with their interviews, in order to identify if the level of participation can be used as a dimension for contextualisation, as it has been suggested by previous educational literature. As expected for an initial design study, the results do not provide "hard" evidence. However, the trend of the results supports the research presumption that the learners' perception of their activity visualisations is context dependent. Moreover, we found that more engaging visualisation also polarised the participants in this group: while contributing participants were attracted to contribute more to the community, it appeared that non-contributing participants got distracted by the same visualisation.

From the results of this qualitative study it can be suggested that the concept of social affordance (Kreijns, 2004) is context dependent. With regard to information visualisation, this implies that the same visualisation can influence learners differently, depending on their level of participation. This supports the initial research question for the design of the adaptation strategy that motivated our research.

Acknowledgements

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Supporting students to self-direct intentional learning projects with social media

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ABSTRACT

In order to be able to cope with many authentic challenges in increasingly networked and technologically mediated life we need to construct opportunities for participants in higher educational settings to practice the advancement of self-directing intentional learning projects. In addition to teaching general strategies for carrying out these projects more emphasis should be put on acquiring some expertise regarding the selection and combination of a diverse set of technological means for own purposes. The various practices that are emerging around social media seem to be a promising field of experimentation in this regard. The knowledge and skills needed to select, use and connect different social media in a meaningful way form an important part of the dispositions in self-directing intentional learning projects. This paper argues for a course design in which participants are not simply engaged in developing knowledge, skills and orientations in regard to curricular subject matter and the use of technology but actively involved in self-directing intentional learning projects with the support of social media. The theoretical framework of this research is inspired by conceptual ideas developed within iCamp (<http://www.icamp.eu>) project. We will illustrate our line of argumentation with some empirical data collected from a pilot course taught at Tallinn University, Estonia.

Keywords

Self-directing intentional learning project, Social media, Personal learning environment, Course design

Understanding self-directing learning projects

An essential aspect of today's postmodern, technologically rich society is to develop the ability to take control and responsibility for our own education, learning, and change. Charles Hayes has claimed that "when we fail to take control of our education we fail to take control of our lives" (Hayes, 1998). Thus, educational experiences need to be constructed in a way that provides opportunities for participants and facilitators to organize and manage their activities in technologically rich contexts. This is an essential aspect to become increasingly a self-directing person (Knowles, 1975) in today's world.

An extensive amount of research about self-direction and related concepts (self-organization, autonomous learning etc.) exists and has produced rather heterogeneous theoretical understandings in the field of education. Most often self-direction in education is defined as "a process in which individuals take the initiative with or without the help of others, in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate learning strategies, and evaluating outcomes" (Knowles, 1975). It is important to note that self-direction does not mean the total isolation and purely individual work and activities, rather it is seen in the social context, where the "self" is influenced by others (Lindeman, 1926).

Candy (1991) offers an overview of the various strands of research that can be found under the label of self-direction in education. Activities and strategies of actors who either want to support or execute „self-direction“ are the focus of a research perspective that Candy calls **activity-oriented**. Such an activity-oriented perspective can either be applied to actors who operate within or outside formal instructional settings. Candy (1991) suggests speaking of *autodidaxy* in reference to the latter and of *learner control* if actors operate within formal instructional settings.

The second **disposition-oriented** perspective refers to personal attributes and orientations that influence the readiness and ability of actors to self-directing learning and change projects in various contexts. Candy distinguishes between *personal autonomy* referring to the more philosophical strand of theorizing that focuses on individual

freedom and *self-management* focusing on the willingness and capacity to conduct one's own intentional change and overall education (Candy, 1991).

While we appreciate Candy's outstanding attempt to clarify the conceptual landscape, we find the term of "learner control" for activity-oriented research on self-direction in the realm of formal instructional settings to be somewhat misleading. We thus simply speak of *self-directing intentional learning projects* (in formal educational settings) in higher education. Nevertheless, we do so from a decidedly activity-oriented perspective.

Selecting appropriate networked tools and services for self-directing intentional learning projects in distributed settings

It seems fair to say that most explicit attempts to foster self-direction in higher education focus exclusively on the shift of responsibility in relation to the scope, focus and depth of the subject matter studied; aspects of pacing and sequencing; and criteria and procedures of evaluation and assessment. It is usually neglected that many individuals in our increasingly networked societies, find themselves regularly collaborating within distributed activity systems (Fiedler & Pata, 2009) in which co-workers are not physically present all the time and in which activities are thus inevitably technologically mediated. Therefore, we suggest that contemporary conceptualizations of "self-direction" in education need to be expanded. Negotiating and making decisions on technological tools and services that are appropriate (or at least promising) for mediating particular activities needs to be considered as an important aspect or "expression" of self-direction in education.

Hiemstra (1994) has stated that taking personal responsibility in education refers to individuals assuming ownership for their own thoughts and actions, which does not necessarily mean control over personal circumstances or environmental conditions in all parts of life. Nevertheless, developing and fostering at least partial personal control over the technological means that mediate and support work- and study-activities seems to be an appropriate and timely educational objective for higher education. We suggest that taking initiative and responsibility for one's own learning and change increasingly includes and requires the ability to select adequate mediating technologies to enrich a *personal learning environment*. We understand personal learning environment as a rather broad and subjectivist concept. A personal learning environment entails all the instruments, materials and human resources that an individual is aware of and has access to in the context of an educational project at a given point in time (See Fiedler & Pata 2009, for more detailed account on this aspect). Networked tools and services offer an ever-expanding variety of means to support, amplify, and enrich our personal environments for learning and change. The ability to gain access to, and choose selectively from a full range of tools, services and other resources thus needs to be considered as an important aspect and expression of self-directing intentional learning and change in education. Negotiating and selecting networked tools and services for collaborative action can help to externalize thought processes, understandings, and expectations within a group of actors that otherwise remain obscure and invisible. While trying out different tools and services actors can become aware of their thinking process, missing knowledge, and lack of understanding. Analyzing what kind of tool or service appear to be suitable for reaching a particular action goal under specific conditions, presumes participants reflecting upon perceived affordances, expectations, orientations, and so forth. In principle, this often requires a trial-error approach to find out how the potential of existing resources can be un-locked and utilized (Brockett, Hiemstra, 1991).

Learning contracts to support self-directing intentional learning projects

Though educational research has largely ignored the need to expand notions of self-directions in the direction of control over technological means to mediate one's productive and conversational actions, it has produced some well researched and validated (cognitive) tools for fostering various aspects of self-direction in education. One such instrument is the personal learning contract (PLC). PLCs usually require some structured, written outline of what and how an individual (or group) intends to achieve within an intentional project of learning and change (Harri-Augstein, 1995). The creation, cyclical adaptation, and elaboration of PLCs is embedded in a set of conversational procedures that normally entail a facilitator and/or peers who help to clarify and explicate the essential components of such a "contract" with oneself. Thus, the main function of facilitators is to support participants drafting, refining, and revising their own contracts.

As we have mentioned above, in adult education the use of “personal learning contracts” that are embedded in a conversational coaching approach are a well documented and evaluated approach (Harri-Augstein, 1995). In its most simple form a learning contract consists of an explication of *purposes* that drive one’s project and that describe what one wants to achieve; a statement on *strategies*, explicates what activities one intends to carry out and what resources might be used; a statement regarding the desired or expected *outcomes* describes some criteria that would allow evaluating if or how successful a project was. What is actually carried out during the project is documented in *records of action*. The core statements on purpose, strategy, and outcome can, and indeed should be, revised and adjusted while the project unfolds. In a final *review* procedure the overall material is used to reflect and analyse the process that actually took place (Harri-Augstein, 1995).

A learning contract applied in such a way, guides an iterative process. Participants can draw parallels between their tentative plans and their actual study process and analyze the differences. This provides an opportunity to identify the direction of development and to formulate the next contract (Harri-Augstein, 1995). The main purpose of such a systematic, practical procedure is to empower participants to think positively and constructively about their study- and work skills and to be more aware of what and how they study (Harri-Augstein, 1995). Learning contracts enable individualisation and externalisation of a person’s thoughts and pursuits in respect to her goals and strategies.

In our teaching experiment we tried to make use of the general format of conversationally grounded PLCs within a landscape of social media tools and services to support the gradual shifting of the locus of control in regard to a variety of instructional functions that are normally provided by the representative of the formal educational system.

Case description

Overview of the course and landscape of social media

The Master’s level course “Self-directed learning with social media” in Tallinn University was designed to create challenging situations for participants to advance their dispositions for self-directing learning projects with the support of social media tools and services.

The course was designed and carried out by two facilitators who work at Tallinn University, Estonia, as researchers and lecturers in the field of educational technology and who are rather proficient users of social media. 26 students participated in a pilot course in autumn 2007. The background of the participants varied a lot. The majority of participants were active secondary school teachers, while the rest were full time master students, who predominantly had gathered some work experience before enrolling for the master program. However, ICT skills varied considerably among the participants. They ranged from being limited to regular use of email clients and Web browsers to high level programming skills.

The course lasted for eight weeks. In this period three full day face-to-face contact meetings were organized. The purpose of the meetings was to give an overview of the course structure and its requirements, to provide some introductory insight to the theoretical concepts, and to provide a glance of a set of networked tools and services that participants might find useful for carrying out assignments in a distributed and mediated work setting. The remaining study activities were carried out from the distance, making use of a variety of networked tools and services.

The facilitators seeded a distributed technological landscape (see Figure 1) on the basis of social media, leaving aside any centralized and closed systems hosted by the institution (Fiedler & Kieslinger, 2006). The central core of this selection of loosely connected tools and services was a course Weblog (Wordpress), where participants were provided with an updated overview of ongoing course activities and necessary materials in the form of Weblog-posts and hyperlinks. In order to get a better overview of the participants’ progress and ongoing activities, a page was created on an open-access mash-up service (Pageflakes) to aggregate the Webfeeds of all participants’ personal Weblogs and to display all the resources that got bookmarked collaboratively on a social bookmarking service (Del.icio.us) for this course.

Furthermore, facilitators or participants could leave messages to the entire group on this mash-up service page. Synchronous communication tools like MSN messenger and Skype connected facilitators and participants for real-

time conversations. Beyond this pre-selected set of tools and services, participants enriched their personal landscapes with a wider selection of social media according to their individual needs and preferences.



Figure 1. Landscape of tools and services used in the course

Course framework

The general purpose of the course was to introduce different learning methods with the support of social media. Special attention was paid to the notion of self-directing learning and change projects. A range of techniques and assignments were given to participants with the purpose to stimulate their self-directed acts. Participants were asked to carry out two assignments, one individually and the other one in groups. For both assignments participants had to think of an authentic work or study activity and come up with the real working technological landscape that supports this particular activity.

The idea of learning contract was used also in the course, but in a slightly modified way as described above. In order to help participants to exercise control over their study activities they were asked to draft an individual personal learning contract for each of the two assignments. Participants were recommended to explicate the core parts of their personal learning contracts each time before they were given one of the two major assignments during the course. The contracts were revised after the assignments had been carried out and then reflected more deeply at the end of the course. Reflection was done in an essay format, where participants were asked to review their personal learning contracts and their actual learning process. Participants reflected in the light of their initial plans and projections upon the actual activities they had carried out and the outcomes they finally had achieved. All individual and group work was supported and mediated by the tools and services the participants had selected. Participants were given complete freedom and full responsibility over their activities and the technological means for supporting their performance. They were encouraged to take control over both, the objectives and the means.

Although participants had been given a final deadline for assignment completion, they were encouraged to follow their own pace while respecting general organizational constraints such as the overall duration of the course. The deadlines of the assignments were meant to function as indicators for planning activities within the organizational time limits.

To foster personal responsibility, facilitators also provided a variety of alternative study resources to participants. In addition to reading materials on various related topics (self-directing learning projects, social media, collaborative learning, learning management systems, and so forth) a set of social media were introduced from which participants later could choose according to their personal needs and interests.

Research design

This research followed elements of action research (Creswell, 2002). It tried to alter a rather traditional approach to course design, while observing the effects of these changes on participants' experiences (Breakwell et al., 2000). The purpose of the research was to bring about changes in course design and the overall learning/teaching process while trying to map and understand the consequences of these changes at the same time.

The overall change process consisted of several interrelated stages:

Stage1: Definition of the changes made in the course design

The first stage of the research was to identify and describe intended changes for the course design. Here we drew from research, debates and discussions generated in the extensive body of literature based on self-direction, aspects of learning environments and use of social media in education and the ongoing work within the iCamp (<http://www.iCamp.eu>) project.

Stage 2: Design and implementation of remedy in the course design

The course was redesigned to incorporate the changes and carried out with master level students.

Stage 3: Observation and data collection

The third stage refers to the actual learning/teaching process, where the changes were observed and data collected.

Stage 4: Analysis of the impact of changes and reflection

This stage investigated students' perceptions of their experiences while participating in the redesigned course.

Research questions

The purpose of this research was to determine the possibility of applying social media for fostering and promoting self-directing intentional learning projects into a master level course design and to investigate students' responses to that learning situation. This research asked the following questions:

1. What were the challenges for the students in this kind of course design?
2. How did the students perceive the concept of self-directing their intentional learning projects?
3. To what extent support personal learning contracts the self-directing of intentional learning projects from the students' perspective?
4. What is the role of social media while self-directing intentional learning projects from the students' perspective?

Data collection

26 students participated in this experimental course. Intrapersonal data was on focus, where cognitive and emotional aspects of the students were considered (thoughts, feelings, attitudes). A direct elicitation method was used for data gathering (Breakwell et al., 2000): in the form of students' essays about their experiences and open-ended questionnaire.

Data analysis

The framework for data interpretation was based on the research questions and the changes that were brought about the course design (personal learning environment, learning contract, reflective task, social media, different role of the facilitator). Data analysis was done qualitatively with the purpose to explicate perspectives of the participants in this course, to interpret and discover patterns within the students' accounts.

Techniques of qualitative analysis recommended by Miles and Huberman (1994) were used to analyze the data collected from the students' essays. The analysis involved a three-step process: data reduction, data display, and conclusion drawing and verification. The analysis was done with the assistance of HyperRESEARCH, a computer-based qualitative analysis program. Data from the essays was initially coded according its set of *a priori* codes that were derived from the research questions together with sub-themes that emerged within these categories.

The process of coding the data is summarized in Table 1. The codes were gradually elaborated by bringing in additional themes as sub-themes while working with the data.

In addition to the students' essays, an open-ended questionnaire was conducted after the course had finished. Open-ended questions allowed students to respond using their own vocabulary and terms to describe their expectations regarding the overall course and the role of facilitators in particular; their challenges and difficulties in this course; their understanding of self-directing intentional learning projects; their opinion about learning contracts as a means for self-directing intentional learning projects; and their previous and prospective use of social media for study or work.

The answers to the eight questions (behavioral, background and opinion/experience questions) of the paper-based questionnaire were analyzed qualitatively. Questions that referred to similar aspects were analyzed together. This was done with questions 1 and 2, 4 and 5, and 6 and 7 respectively. The analysis followed a top-down approach in which the data was categorized according to *a priori* codes based on the research questions and the changes made in the course design. As the number of the students and the length of their answers were not that extensive, data analysis was done manually. 24 from 26 participants returned the questionnaire.

Table 1: Steps of the data analysis

| Analysis process | Rationale | Software |
|--|---|----------------|
| Data Reduction process: cutting words and phrases that were not relevant for the current analysis; segmenting data | Reduction of the data in order to discard, sort and organize the data in a way that allows to collect reasonable segments of data | Scrivener |
| Coding: coding text according to <i>a priori</i> codes determined by the research questions and the changes made in the course design as well as inductive codes which emerged from the data | Coding of the data in order to focus, organize and process data | Hyper-RESEARCH |
| Sub-coding: codes were revised and compared within the data collected from the essays as well as with the data collected from the questionnaire with the purpose to merge them into categories based on their relationships | Sub-coding of the data in order to abstract and condense the data for permitting conclusion drawing | Hyper-RESEARCH |
| Ordering and displaying: themes were determined and generalizations were made. | Taking the reduced and coded data and displaying it in an organized, compressed way through such means as selection, paraphrasing and subsuming in a larger pattern that permits conclusion drawing | Hyper-RESEARCH |
| Conclusion drawing: conclusions were made and written up | Decisions about the meaning of data and testing validity of findings by noting regularities, differences and similarities, explanations and propositions were made | Scrivener |
| Verifying: conclusions were verified by referring back to the original data | | |

The overall data analysis was initially done separately for the essays and the questionnaires. After the coding system had begun to consolidate, the data from both instruments was merged.

Results

What were the challenges for the students in this kind of course design?

One of the purposes of this course design was to create challenging and authentic situations for the students regarding the technological support of their own learning environments and taking initiative and responsibility for their activities.

Although it was mentioned in some students' essays that they had experienced some kind of problems, the questionnaire results showed that 5 students out of 24 claimed they had had no major difficulties and challenges in this course. However the main challenges were the following:

1. Challenges related to terminology
2. Challenges related to learning contracts
3. Challenges related to assignments (individual and group work)
4. Challenges related to tools and services

Challenges related to terminology

The analysis of the questionnaire and essays showed that 11 students experienced information overload in the beginning phase of the course. Insufficient explanation about new terms and concepts resulted in some students feeling frustrated. They claimed they had received too much new information and new terms at the same time, which made it complicated to make sense out of this oversupply. The students said:

„The terminology was new and not understandable for me“

„In the beginning I thought I need a dictionary, because so many new terms were mentioned“

It is ineluctable that the introduction of new concepts, new tools and services as well as an unusual course design carries terminology that is not necessarily familiar to the students. One student found the whole course design with its activities quite challenging while two other students claimed that they had only experienced problems understanding the concept of self-directing” their learning projects. The students said:

„The subject and the structure of the course were new to me“

„In the beginning the whole course appeared like rocket science“

Challenges related to learning contracts

Challenges related to the learning contracts refer mainly to the early stages of formulating the different parts of such a contract. Seven students claimed they had experienced problems trying to explicate their goals, strategies, tools and evaluation criteria. The students said:

„It was complicated to formulate the evaluation criteria. My whole life others have decided that“

„All of the sudden I had to think through my whole learning process – what exactly am I going to do now? What do I want to achieve?“

Very few students had heard about learning contracts and for some of them it was unclear why it had to be done, especially since it did not form a major part of the final grading. The student said:

„I didn't understand the need for creating a learning contract... why do I have to do this?“

It was obvious that most students were not ready to take initiative and responsibility for their own learning. The main reason seemed to be a lack of experiences and rationale in this regard.

Challenges related to assignments

19 students out of 26 claimed that the first assignment was difficult, confusing and unclear. The main reason for this appears to be the new terminology used by the facilitators and the unfamiliar distributed course environment.

While the first assignment was confusing for most students, the second assignment that focused on group work was readily understood. However, some other challenges occurred.

Eleven students claimed that group work on the distance was complicated because of unreliable technological tools and services, such as synchronous editing of web-based documents or schemes. The students found it very time consuming to find a common understanding among group members, to communicate, and to regulate the group's activities without meeting others face to face. The students said:

„Group work was especially difficult for me as I had never done it in this way“

„I must say that it is very difficult and time consuming to carry out group work on the distance“

Four students found it difficult to find common time frames for the group work to discuss issues synchronously. The students said:

„It is very difficult to find a common time frame that is suitable for everybody“

„Unfortunately the members of the group had so different time schedules and therefore taking common action was rather limited“

However it is interesting to note that the students did not encounter problems choosing the right tools and services for carrying out their group assignments on the distance.

In addition, a couple of students considered it unusual presenting home assignments in their personal Weblogs in a format that was public and easily accessible. The student said:

„But the idea to put everything to my Weblog didn't put a smile on my face“

Challenges related to tools and services

The questionnaires and essays showed that all the students were familiar with e-mail services prior to the course. Some of the students had had experiences with video- and photo-repositories as well as Weblogs. Weblogs had been mainly used in other course settings. However the majority of the students were unfamiliar with the tools and services introduced and used during the course (see Table 2). Not surprisingly the main challenges that emerged from the learning process were related to new tools and services as well as the learning environment as a whole.

Table 2: Tool use before and after the course

| Type of tools and services | Tool use before the course | Potential tool use after the course | Possible explanation |
|---|----------------------------|-------------------------------------|---|
| Social bookmarking (Delicious) | 6 | 11 | This tool was part of the course environment and the students were obliged to create an account in order to be able to find their Weblogs |
| Video repositories (Youtube, Google video) | 10 | 1 | Due to the prior use of these tools and services the students might forget to mention them again |
| Photo repository (Flickr) | 7 | 0 | |
| Weblog (Wordpress, Blogspot) | 9 | 17 | Weblogs were used in the course as one of the obligatory tools |
| Aggregators (Netvibes, Pageflakes) | 4 | 9 | An aggregator was part of the course environment |
| Collaborative writing and drawing (Google docs, Gliffy, Vyew, Bubble) | 4 | 9 | Their applicability were tested and proved while doing group work |
| Web-based office (MS Office | 2 | 3 | These tools were not directly used in the course, |

| | | | |
|--------------------------------------|---|---|---|
| Live, Zoho) | | | neither by facilitators nor the majority of students |
| Wiki (Pbwiki) | 1 | 4 | |
| Presentation repository (Slideshare) | 0 | 3 | This tool was used by the facilitators during the face to face meetings |

Six students from 24 claimed that they had difficulties with the large number of different tools and services introduced during the course. This meant it was challenging to keep up with understanding the purpose and use of these tools and services. Furthermore, the students considered the registration processes, getting oneself acquainted with tools and services, as well as remembering all the login details (mentioned by five students) as challenging. The biggest challenges for two students were finding and combining tools and services, and getting an overview of the overall landscape of tools.

Furthermore, two students claimed they had not enough time to go through all the tools and services in depth, since their level of interest in the tools and services and the overall course pace was not aligned.

In conclusion, the main challenges for students in this course were related to the assignments they had to carry out, since they differed from the type of assignments usually found within traditional course designs. Another major area of challenge was the array of technological tools and services used to support personal learning environments.

How did the students perceive the concept of self-directing their intentional learning projects?

To answer the second research question, the questionnaire was designed to capture the students' insights and opinions regarding the notion of self-directing intentional learning projects. The questions aimed at eliciting positive and negative aspects of self-directing intentional learning projects from the students' perspective.

Ten students pointed out that the most important aspect of self-directing one's own learning is the freedom to choose one's goals, strategies, means, and resources. It is interesting to note that one student focused on the importance of self, self-consciousness and responsibility. The student said:

„When the self and my purposes become more important than what the others expect from me...“

Four students understood the concept of self-directing intentional learning as a constant and conscious development based on one's intrinsic motivation. Three students thought that it is about defining one's needs and interests, and ways how to learn accordingly. The students said:

„Keeping a diary, which means organizing oneself “

„Motivating oneself, reflecting on one's activities and outcomes and defining future direction“

„Analyzing failures and success of one's activities“

The positive aspects regarding the concept of self-directing intentional learning projects were the following: ten students thought that the freedom to choose is the main advantage. This included the possibility to plan one's learning process and topics based on one's needs and interests, the possibility to choose resources, and to follow one's own pace. Furthermore, the possibility to combine work, study and home were considered equally important.

However, the essays showed that too much freedom and lack of structure can create chaos and can be seen also as an inhibiting aspect for the learning process. Setting up one's goals independently can be seen as positive and negative, since most students experienced that it is not that easy to clearly define one's goals. Some of the negative aspects that were brought up by four students were motivation and responsibility while carrying out self-directing intentional learning project.

Three students pointed out that the unlimited opportunities to acquire new knowledge and information were a positive aspect. One interesting aspect brought out by one student was the following:

„I have to think how to make the best out of the resources that I have at a certain point in time“

Three students thought that the lack of feedback and lack of others support were negative aspects. Wavering from the initial goals, lack of self-belief and fear of failure were mentioned by four students. One student considered the

misunderstanding of the assignment as a drawback. Another student was afraid of making wrong choices in terms of supporting tools and services.

To what extent support personal learning contracts students who are self-directing their intentional learning projects?

In general 21 students from 24 found learning contracts useful and supportive for self-directing their intentional learning projects. Students gave quite different answers in regard to the usefulness of the learning contracts in one's learning process. The following aspects were pointed out:

- 20 students said that it was needed to document activities since it gave a clear overview of what, when and why.
- one student claimed that it offered a clear structure for learning and it helped to develop knowledge
- ...it became personal and it motivated
- ...it supported the achievement of better goals and outcomes
- two students thought that it helped the evaluation of development and the measurement of one's achievements
- two students claimed that it helped to concentrate and choose the focus point, and to coordinate and direct one's activities
- ...it helped to determine what the important activities were
- ...it made a person think

Two students claimed that the learning contracts did not make sense for them and were useless. The students said:
„This is just an expression of forming one's thoughts and goals“

However one of them saw the general importance for other learners as a support for concentrating and focusing on important aspects in one's learning process.

What is the role of social media while self-directing intentional learning projects from the students' perspective?

As it is seen from the table above (Table 2), the perceived probability of using social media in the future was quite high. 18 students claimed that they intend to make use of some of these tools and services in the future to support their leisure, study or work related activities. Some of the students reported that this course encouraged them to investigate different social media. The main reason for a continued use and exploration of new tools and services is the perceived simplicity and variety of choices and functionalities found in social media. Social media enable for example to provide continuous feedback, to carry out reflective tasks, to draw schemes either individually or in groups synchronously, to mediate group communication, and to work together on common artifact. The students said:

„Social media give me an opportunity to carry out my tasks despite of the location and the nature of the tasks“

„Social media applications are very effective, not only for the execution of self-directing intentional learning projects but also useful in very different context and conditions“

Despite of these perceived benefits the students wished to receive more supervision and practice for using different social media. From their perspective too many tools and services were introduced in a rather short period of time. Due to the limited time frame they found that their understanding of the tools' nature and their ability for using them remained somewhat superficial.

Discussion

The findings suggest that our re-designed course indeed created some challenging situations for students. The personal reflections on the activities varied a lot among students. They ranged from an experienced match of the activities with predefined personal goals and strategies, to explicit dissatisfaction. A major source of dissatisfaction with the process and outcome appeared to be a feeling of information overload in the beginning of the course and confusion around the given assignments and terminology. Quite many students claimed that in the end of the course

they were able to write down their goals and how to reach them. On one hand, this is a fairly common pattern for novices who try to explore a new domain of knowledge and skill, on the other hand this might indicate that the instructions for the assignments were not clear enough. Some students found it hard to obtain an overall image of the course and its specific assignments and components.

The students predominantly claimed that they had progressed a lot during the course and that this had changed their initial goals and understanding. They understood that the social media they worked with are also applicable in other contexts beyond educational settings, since these tools and services afford to carry out many different activities.

The essays showed that most of the students were rather self-critical in their evaluation of their capacity to identify their own needs, to develop personal learning contracts to meet these needs, and to achieve the goals that they had described within the contracts. It was obvious that the externalization of one's own thoughts and strategies was something rather novel and challenging for all students, since most of the courses in higher education largely ignore students' own learning goals and personal learning environments.

In our re-designed course students found the personal learning contract procedure very useful. One reason for its perceived usefulness seemed to be the instrumental value of the learning contract material for writing a reflective essay on their overall experience and process at the end of the course period. The personal learning contract procedure was described as a means and tool to keep them on track, to structure their own activities, and to monitor their success. Furthermore, students considered the learning contract procedure as a good way of documenting their ideas and thoughts, coordinating their activities and providing means to measure their achievements. They interpreted the learning contract as their own personally constructed "instruction" or guideline for their activities. Some of the students found it motivating, as they were recommended to write down in detail what, how and when to work and study. This provided them with a compact overview of the direction to pursue and the rationale behind their activities. Some students reported that the contracts helped them to concentrate and focus on their activities and not to deviate from the initiated path. Writing down goals and needs turned them into something personal and important for the author, giving her a feeling she was in control of her own activities.

After completion of the assignment many students understood that their predefined evaluation criteria did not make sense and were not really measurable. Furthermore, evaluating themselves seemed to be a new and rather challenging task. It was obvious that the first assignment was quite time-consuming and demanding, due to numerous new terms and social media. This certainly added to the initial problems that students experienced while they were trying to specify detailed goals and strategies. It seemed easier for most students to draft their second learning contract in relation to the group assignment, after they had explicated their goals and purposes, strategies, and intended outcomes already once before in the context of the individual assignment.

However, it appears that different tools and services and new concepts and terms should be gradually introduced over the course period. All students claimed that they had a rather positive experience regarding the acquisition of useful theoretical knowledge and practical skills in respect to the use of social media tools and services and self-directing their own learning projects within formal educational settings and beyond.

Conclusions

It is obvious that outside of formal educational settings individuals (and groups) cannot rely on educational authorities and formal instructional systems to structure and support their activities. We assume that formal education for adults should be designed in ways that allow all students to actually execute and advance their dispositions for self-directing intentional learning projects in general, and within distributed and net-worked settings in particular.

This paper described a redesign of a master's level course called "Self-directed learning with social media" that intended to foster the ability of students to self-direct intentional learning projects in distributed settings. Thus, a significant aspect of this course design was the provision of opportunities to practice the selection of social media for mediating particular activities.

The reflective essays of the participants on their individual learning processes and the administered questionnaires were analyzed to gain an insight into how students experienced their own ability and effectiveness to plan, organize, and manage their own work- and study-activities. The reports of the students and the digital traces of their activities showed quite clearly that they gained considerable knowledge and skills regarding the use of social media for supporting a range of activities. It can be concluded that students indeed acquired some expertise regarding the selection and meaningful combination of a diverse set of social media for their own purposes.

However, it is important to note that rather isolated and short-lived interventions that are constrained by the academic semester rhythm make it difficult to observe any significant changes of students' readiness and capacity for self-directing their own learning and change. Nevertheless, we believe that the course design presented in this paper offers a promising and feasible approach to foster the advancement of a set of dispositions (knowledge, skills, orientations) for self-directing intentional learning projects in distributed settings that are viable for coping with many authentic (educational) challenges in today's increasingly networked and mediated life.

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Self-Development of Competences for Social Inclusion Using the TENCompetence Infrastructure

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ABSTRACT

This paper describes a pilot study centred on the technology-enhanced self-development of competences in lifelong learning education carried out in the challenging context of the Association of Participants Àgora. The pilot study shows that the use of the TENCompetence infrastructure, i.e. in this case the Personal Development Planner tool, provides various kinds of benefits for adult participants with low educational profiles and who are traditionally excluded from the use of innovative learning technologies and the knowledge society. The self-organized training supported by the PDP tool aims at allowing the learners to create and control their own learning plans based on their interests and educational background including informal and non-formal experiences. In this sense, the pilot participants had the opportunity to develop and improve their competences in English language (basic and advanced levels) and ICT competence profiles which are mostly related to functional and communicative skills. Besides, the use of the PDP functionalities, such as the self-assessment, the planning and the self-regulating elements allowed the participants to develop reflective skills. Pilot results also provide indications for future developments in the field of technology support for self-organized learners. The paper introduces the context and the pilot scenario, indicates the evaluation methodology applied and discusses the most significant findings derived from the pilot study.

Keywords

Lifelong competence development, Self-organized learning, Social inclusion, Pilot study, Non-formal learning

Introduction

The emerging knowledge society places new demands on individual workers, groups, and organisations. Central to these demands is the need to continuously develop and manage the competencies which provide competitive advantages (Koper, 2008). To achieve lifelong competence development there is a need for better integration of learning and knowledge dissemination facilities offered by the different knowledge support organisations in society, e.g., educational institutes, training departments, HRM support organisations, government, libraries, research institutes and others. The requirements placed on the models and technologies to support such integrated facilities differ considerably from those traditionally placed on technologies to support particular fragments of a learning lifetime, or to serve the knowledge dissemination and knowledge management needs of a company. One requirement is that such an infrastructure should support self-directed, self-organized learning, which is often seen as a main characteristic of lifelong competence development (Cheetham & Chivers, 1996) and of learning in adulthood generally (Knowles, Holton, & Swanson, 2005; Merriam, Caffarella, & Baumgartner, 2007)

The TENCompetence project is a four-year project in the European Commission's 6th Framework Programme, priority IST/Technology Enhanced Learning. The aim of the project is to design a technical and organizational infrastructure for lifelong competence development. The project develops new innovative pedagogical approaches, assessment models and organisational models, and it creates a technical and organizational infrastructure which integrates existing isolated models and tools for competence development into a common framework (Koper & Specht, 2006).

The TENCompetence infrastructure is validated in a number of different pilots, representing the variety of contexts in which lifelong competence development takes place (Schoonenboom et al., 2008a). The main research question underlying all pilots is: For whom does the TENCompetence infrastructure work in a variety of circumstances? More specifically, we want to know to what extent the use of the TENCompetence infrastructure leads to the kind of self-directed and self-organized learning that is typical for lifelong competence development. First experiments with highly educated people (Schoonenboom et al., 2008b; Moghnieh et al., 2008) showed that use of the TENCompetence infrastructure helped people in developing their competences, made them feel more in control of their own learning, and made a number of people change their preferred way of learning from following a pre-determined learning path in a strict order to being able to choose their own learning path.

In the Àgora pilot, we investigated to what extent these findings also apply to people with low educational levels who are working in a non-formal learning environment. The pilot took place in the context of the Association of Participants Àgora, which is a non profit association of adults who do not have any academic degree and are characterized by their intrinsic motivation to learn. The main goal of the association is to promote the educational and social inclusion of its participants grounded on democratic participation (Sánchez-Aroca, 1999; Flecha, 2005). This context is challenging in the domain of self-organized/self-directed learning as the lifelong learners involved have typically low educational profiles and have not always the necessary confidence to take the primary responsibility for the planning and performance of learning activities. In addition, we expect that these learners in general have low computer skills, which are probably too low to make sensible use of the TENCompetence infrastructure. Thus, we would expect that it would be much harder, if not impossible, to achieve lifelong competence development in the Àgora pilot, as participants (1) may not have the necessary planning skills for self-organized and self-directed learning, or (2) the necessary computer skills, and (3) in a non-formal learning context, it will not be possible to oblige participants to acquire these skills or to continue competence development.

The aim of this paper is to present the Àgora pilot and its results concerning the benefits of TENCompetence when applied to this special context. In order to reach the objectives of the pilot, the TENCompetence infrastructure was used so as to provide learners with a set of self-training functionalities to support their competence development process. In this framework, the participants were responsible for defining their own learning path including goal setting, self-assessment, planning and self-regulated learning among others.

The paper is organized as follows. In the first place, it describes the Àgora pilot presenting on one hand the challenging context of Àgora and on the other hand the pilot scenario and the TENCompetence usage profiles and tools applied. Secondly, the paper focuses on the description of the methodology employed for evaluating the pilot study, and as well as on the results and discussion of the main findings. Finally, the paper presents the conclusions of the pilot study.

Description of the Àgora Pilot

Àgora context

The Association of Participants Àgora, as part of *La Verneda-Sant Martí* Adult Education Centre, is an organization dedicated to the non-formal training of lifelong learners. Àgora, which is located in the Sant Martí district in Barcelona, provides a daily educational setting for about 1600 participants, more than 100 volunteers and ten hired staff. It has an extended opening time from 9am to 10pm from Monday to Sunday. All the activities offered are free-of-charge and include language learning (Catalan, English, German, Spanish, French, Arabic, etc), basic literacy, ICT training groups (Women and ICT; Towns of the world, etc), preparation for University access tests and dialogic literary circles among many other workshops. Àgora is based on democratic participation, opening all decision-making spaces to any participant of the organization. The participants are mainly adults who have been excluded from formal education, i.e. adults without any academic degree, young adults coming from scholastic failure, women, immigrants and people with special needs, and are characterized by their intrinsic motivation to learn. The general aim of Àgora is to promote their social and educational inclusion through the dialogic learning methodology, which focuses on the inclusion of the voice of all participants and based on egalitarian dialogue, transformation and solidarity among other principles (Flecha, 2005). In this line, one of the main challenges of Àgora is to explore new ways to support a wide range of competence development and knowledge sharing for adult lifelong learners.

Àgora has an extensive experience in the ICT sector, and since 1999 the association manages and administers an OMNIA located within the association (computer rooms distributed over Catalonia by the local government to facilitate access to ICT for those with difficulties to make use of them). The OMNIA computer room was provided as a result of the participants' *dream* of being part of the "information superhighway" and was achieved through their consensual decision to seek the necessary means to be fully integrated in the information and knowledge society (Sánchez-Aroca, 1999). The main aim is to promote the access to ICT for all the people of the neighbourhood. Another key objective of the computer room is to facilitate access and promotion within the labour market starting from the training (e.g.; learning to write documents, use the e-mail and search for information on the Internet efficiently) and the professional re-training (e.g.; keeping people with some professional experience up-to-date about recent developments in ICT). Eventually, one of the main priorities of Àgora is to use the ICT as a learning tool in all the courses offered, as for instance through the use of smart boards.

Finally, it is worth mentioning Àgora's policy in terms of competence development. Àgora mainly focuses on the development of functional skills by offering literacy, digital literacy and numeracy courses among others. In addition, the participants develop cognitive competences on the basis of the recognition of the knowledge acquired in informal learning contexts. Moreover, the education in Àgora is centred on the promotion of communication skills through the use of dialogic learning, as for example the organization of the classroom in interactive groups, in which the participants share knowledge and ideas rather than performing individual learning. The philosophy of Àgora is centred on values and ethical competences through the adherence to the Participants' Bill of Rights (FACEPA, 1999), which is an international reference document defining the social, democratic and participative model of adult education aimed at overcoming social inequalities. After having defined Àgora's context, the next section will describe in detail the Àgora pilot experience.

Pilot scenario: Self-training of intrinsically motivated lifelong learners

The Àgora pilot took place mainly in the OMNIA computer room (see Figure 1) of the association equipped with 9 computers and was carried out between mid-September and the end of October. The computer room was reserved for using the TENCompetence infrastructure during 14 weekly hours. Participants had also the possibility to use the TENCompetence tools whenever the OMNIA was free, including the week-ends and after the end of the pilot. Besides, the participants also use the tool at home. The main aim of the pilot was to implement, test and investigate the benefits of the TENCompetence infrastructure and its support for the participants' competence development. The ten competence profiles from which participants could choose included ICT (MS Word, E-mail usage, Internet, MS Power Point, Windows management, Files management, Folders management, Blogs usage) and English language (basic and advanced levels) . For each competence, participants could choose between several activities, ranging from 3 to over 20 activities per competence. One activity stands for between 15 minutes and 3 hours of learning.



Figure 1. Participants using the TENCompetence tools in the Àgora computer room

The pilot comprised more than 100 learners; 7 experts (Àgora staff) and 13 ICT collaborators (members of the Àgora ICT commission) and other Àgora staff interested in using the tool, apart from the researchers involved in the investigation. The wide range of adult learners who participated in the pilot varies in terms of age, gender, but also in the variety of needs and interests. Most of them have low academic levels and are characterized by their intrinsic motivation to learn. A TENCompetence expert was in charge of each of the self-training session to assist the users with any technical or content-related issue.

TENCompetence usage profiles and tools applied in the pilot

A second version of the TENCompetence infrastructure was delivered in June 2008. This version consisted of the TENCompetence server and a client software package, called the 'Personal Development Planner' or PDP for short (Martens & Vogten, 2008; Koper, 2008). The pilot participants used the PDP as the central tool for the creation of their own personal development plans by selecting a competence profile, stating their goal and motivation, following a self-assessment, creating their learning plan and performing the activities in the plan (see Figure 2).

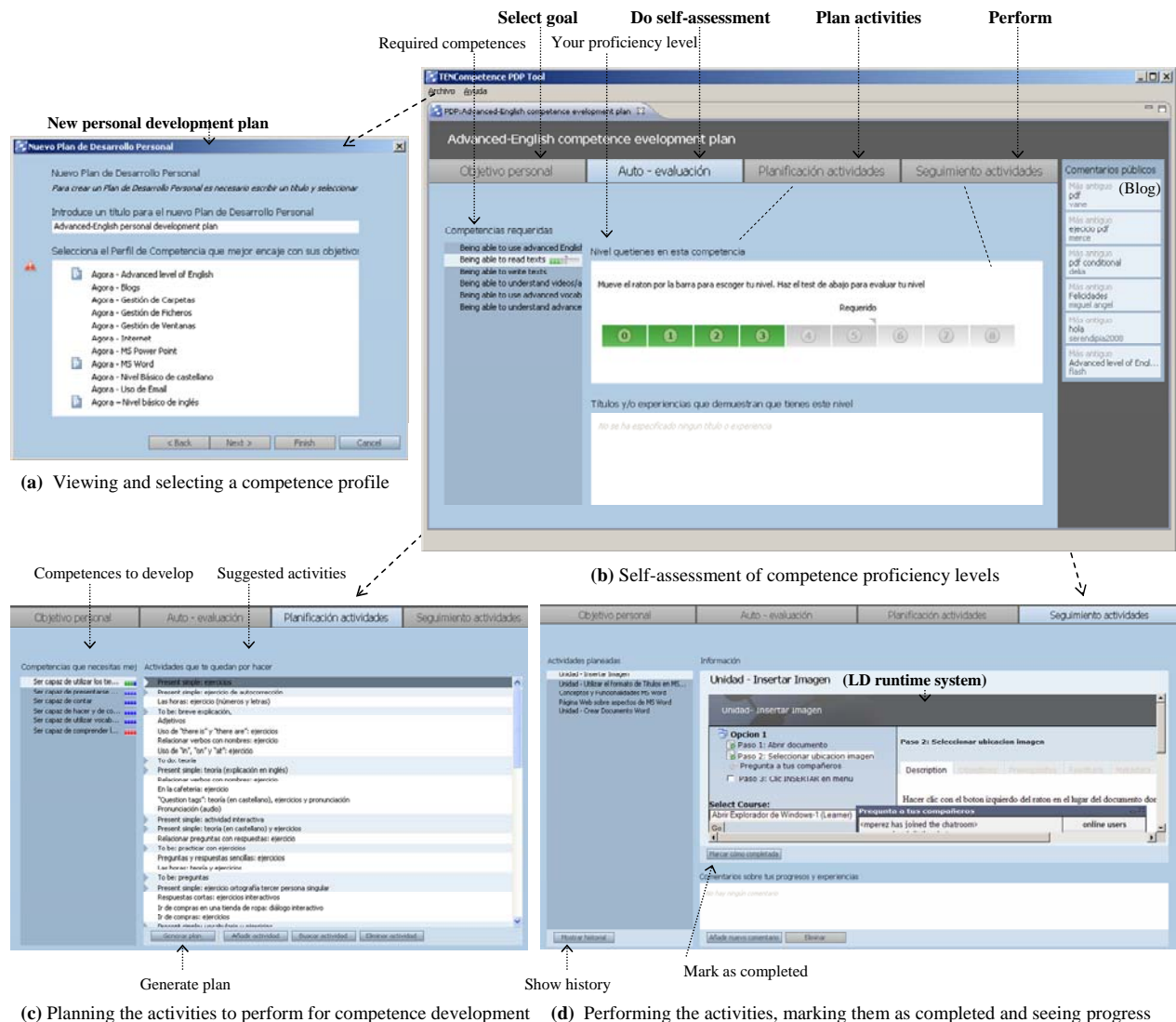


Figure 2. TENCompetence Personal Development Plan functionalities as experienced by Àgora pilot participants (in Spanish)

Figure 2 (a) shows the PDP facility that allows learners to select one or more of the above-mentioned competence profiles. After specifying the goal and motivation of having selected a competence profile, learners could do a self-assessment as illustrated in Figure 2 (b). The self-assessment consists in a likert scale that enables learners to indicate a proficiency level for each competence (E.g., in Figure 2 (b) the user is indicating that s/he has a level of 3 out of 8 in the competence "Being able to read texts in English"). The competences have a target proficiency level, determined by the Àgora experts beforehand, that must be attained to meet the requirement of the competence profile (in the case of the competence "Being able to read texts in English" as shown in Figure 2 (b) the target proficiency

level is 5). Figure 2 (c) shows the “plan activities” PDP functionality. Clicking the “generate plan” button the PDP automatically suggests a list of activities associated to the competences that the learner needs to develop (e.g., activities that facilitate further acquisition of English reading comprehension). This functionality takes into account that a learner may have a proficiency level beyond the targeted for the profile. When this is indicated in the self-assessment for one or more competences, the generated plan does not include the activities devoted to the already mastered competences. However, the current version of the PDP does not consider the specific proficiency level (when lower than required) for a more accurate recommendation of activities.

The planned set of learning activities can be performed in the PDP as illustrated in Figure 2 (d). The activities are shown on the left hand side panel of the screen. The right hand side provides details about the selected learning activity. This includes a descriptive text of the learning activity, which may include hyperlinks to external learning environments. In the Àgora pilot some activities devoted to ICT competences, for example, were run in the TENCompetence LD runtime system (Sharples, Griffiths & Scott, 2008). The LD system is compliant with the IMS Learning Design specification (Koper & Oliver, 2005) and facilitates the provision of structured activities (similar to courses) that learners can follow as part of their competence development. Figure 2 (d) shows how the LD runtime system can be accessed through the PDP for the activities that make use of it. The PDP facilitates learners to reflect on the progress made by allowing them to mark an activity as being completed. The completed activities disappear from the list of activities to be performed (left hand side panel) but they can be checked again by clicking the button “show history”. Learners can also post public comments using the blog available in the PDP.

Evaluation of the Pilot

Evaluation methodology

The Àgora pilot involved an authentic lifelong learning situation, in which participants in several sessions worked not only on their competence development, but also on mastering the software tools used for their competence development. Learners with varying backgrounds and characteristics worked on their competence development in a developing context, which changed from session to session. As a result, a simple pre- and post test alone would not be sufficient to capture this complex process of change. Therefore, an observational method in which data is collected as the pilot develops was applied (Zelkowitz & Wallace, 1998). In particular, a mixed evaluation methodology, combining the qualitative and quantitative data gathering techniques shown in Table 1, was followed (Creswell, 2003). Quantitative data were considered useful for showing tendencies. Besides, qualitative results were used to confirm or reject those tendencies, to understand them, and to identify emergent outcomes in the specific situation under study (Goubil-Gambrell, 1991).

As indicated in the Introduction, the main goal of the pilot is to investigate to what extent and how the TENCompetence infrastructure ‘works’ for people with low educational levels who are working in a non-formal learning environment and who have not the necessary confidence to take the primary responsibility for the planning and performance of learning activities. ‘Does the TENCompetence infrastructure work’ was operationalized as much as possible in the same way as in previous pilots, which used questionnaires, but additionally qualitative data were collected and log file analysis was performed. As in earlier pilots, the general research question was split into four different sub questions. Below, we describe for each sub question how it was operationalized.

The first question is on the participants’ background. In a pre-test we collected information on participants’ age, gender, country, education, profession, level of expertise on the pilot competences, experience with web-based and competence-based learning, and reasons for following the pilots. The preferred way of learning was measured in the pre-test by asking participants whether they preferred to be guided entirely by the system, to receive suggestion from the system on planning their learning path, or to be provided with learning resources only.

The second question is to what extent and how participants made use of the functionalities provided by the TENCompetence infrastructure. These functionalities included self-assessment, activity planning and selection, performing learning activities on the SLED server, marking activities as completed, blog entries and other means of interaction. In a post-test, a variety of questions was asked, depending on the nature of the functionality, which included: whether, how much, how, for what purpose participants used it, if they did not use it, why not, the difficulty and appreciation of using it and the use of alternatives (blogging only). We asked participants to fill in a

number (how much), or used closed questions with either a yes/no question (whether), a five-point Likert scale (how much, difficulty, appreciation) or a list of alternatives (for what purpose, why not, use of alternatives). Further, we asked whether their learning was hindered by technical problems. An example question is: How would you rate the possibility to mark activities as completed? (very useless..... very useful).

Table 1. Data sources for the evaluation of the pilot and labels used in the text to quote them

| Data source | Type of data | Labels |
|---|---|--|
| Questionnaires before (pre-test) and after (post-test) the pilot experience | Quantitative participant characteristics, expectations and evaluation. | [pre-test] [post-test] |
| Observations during the pilot | Record of observations (technical issues, about the activities, interactions with experts and other participants, behaviour, other incidents, etc.) The observations were done by 6 different experts (Àgora staff, UPF researchers) | [observerX-date], where X represents different observers (from 1 to 6) and date is the specific date when the observations were done |
| Focus group with participants | Qualitative: participants' opinions two weeks before the end of the pilot | [focus-participants] |
| Focus group with experts | Qualitative: experts' opinions two weeks before the end of the pilot | [focus-experts] |
| Log files | TENCompetence server logs, analysis of 512 sessions (a session is considered one usage period of a user from login to logout) | [logs] |
| Description of the Àgora context | Qualitative descriptions of the context characteristics in which the pilot is framed (see "Description of the Àgora pilot") | [context] |
| Observations post-pilot | Records of opinions and observations of what was being perceived in Àgora once the pilot had finished (collected by Àgora staff) | [observations-post] |

The third question is to what extent the use of the TENCompetence infrastructure contributed to lifelong competence development. In the post-test, the following four closed questions were asked, related to different aspects of lifelong competence development:

- (1) How many hours did you spent and (2) how many activities did you complete within each competence profile (estimation)?
- (3) How much have you learned with respect to the following types of competences (knowledge, functional skills, social skills, knowing how to guide their future use)?
- (4) Do you wish to continue developing this competence / these competencies further?

Aspect two and three were measured using five-point Likert scales ranging from 'almost nothing' to 'very much' and from 'certainly' to 'certainly not' respectively. For each competence profile in question one, five answer alternatives were presented, depending on the total number of activities available within the competence profile involved.

The fourth question considers the appreciation of the type of learning offered by the TENCompetence infrastructure. One overall statement was presented: 'I enjoyed this way of learning'. Further, three scales were developed that measured the appreciation of the learning resources, the appreciation of collaboration with other participants and the amount of control over their own learning that participants experienced. Each scale contained a number of statements, to which the participants could indicate on a five-point Likert scale to what extent they agreed with the statement.

The scales on the appreciation of collaboration with other participants and the amount of control of their own learning turned out to be very reliable (Cronbach's alpha of .86 and .82 respectively). As Cronbach's alpha of the appreciation of the learning resources was only .64, the items of this scale were treated separately and not as one

scale in the analyses. On the questionnaire data, descriptive analyses were performed, and the resulting percentages of participants that chose a particular answer alternative were used as the input for the triangulation (Guba, 1981; Creswell, 2003).

The log files generated by the TENCompetence infrastructure also provided quantitative data on the time spent and the PDP functionalities used by the participants (Glahn et al., 2008). The quantitative results are complemented with the qualitative observations gathered by six different observers throughout the whole pilot in Àgora computer room (see Figure 1). Post-observations were also collected in order to understand the informal reactions of the participants when reflecting about the pilot outcomes. Two different focus groups that addressed both participants and experts separately were conducted two weeks before the end of the pilot following the critical communicative methodology typically used in Àgora (Flecha, 2005; Renshaw, 2004). In this way, the focus group consisted of a group of people discussing in equalitarian terms towards understanding the benefits and limitations of the TENCompetence tools and approach applied to the pilot. The researcher is one more person in the group and adopts a listening attitude.

In the triangulation process, from the juxtaposition of the separate answers on the survey questions and the separate pieces of the qualitative data, we sought for meaningful relations that would summarize or explain the specific configuration of results that we found. To take the first insight that we thus found (see Table 2) as an example, we identified the diverse and relatively low level of education, the low experience with competence-based training, the divergent experience in using the computer, and the technical problems that participants experienced as factors that might have hindered their involvement in the pilot. Then we observed that most of the participants completed the pilot experience, and a large majority of the participants including the less experienced used most of the PDP functionalities, and we concluded that these possibly hindering factors in this pilot actually did not really hinder competence development, or that people maintained full use of the pilot possibilities *despite* these hindering factors.

Results and discussion

Table 2 summarizes the findings and partial results after evaluation. The results are discussed in more detail through this section. The first finding evidences that a pilot centred in technology supported self-training can be successful despite the diversity in the participants' background even when most of them have low educational levels. The quantitative results of the [pre-test] indicate that there were a total of 104 participants, comprising 68 women and 36 men. Some of them did not complete primary school (5%) others did complete primary school (22%), secondary school first stage (12%), secondary school (20%), higher vocational education (18%), and obtained an university degree (12%) [pre-test]. This data can also be explained by the [context] of Àgora association as it is mainly addressed to people with low academic degrees. In general, the computing skill and the experience of participants with competence-based training are low, i.e. 61% of the participants either had never followed a competence-based training, or didn't know what competence-based training was [pre-test]. The low educational level of the participants did not prevent them from completing the pilot experience as was shown by the 82 participants who filled in the [post-test] questionnaire. After verifying with the participants themselves, the non-attendance of the 22 remaining participants in the last session of the pilot was mainly due to health problems; the preference to use the PDP at home and at a lower scale because of the difficulties in using the computer [observations-post]. In addition, the [post-test] indicates that the extent to which the learning process was hindered by technical incidents (e.g., Internet down or small windows interface to perform the activities) differed among the participants, i.e. that 35% was hardly hindered or not at all, 41% was moderately hindered and 24% was completely hindered. However, it was observed that the technical issues that arose in the pilot were not a barrier for the participant learning progress as observed by an expert *"...in general, the participants show satisfaction and are in favour of continuing to learn despite of the technical failures that may occur* [observer3-08/10/2008]."

Table 2. Main conclusions offered by the research carried out along the pilot

| Findings | Partial results | Support data |
|---|--|--|
| 1. Technology supported self-training can be useful and beneficial despite the diversity in the participants' background, even when most of them have low | Although participants' educational levels is very diverse (the large majority not having any higher education degree), their experience with competence-based training is low and they have a divergent experience using the computer: - most of them completed the pilot experience; | Based on the analysis of the pre-test, post-test, context, observations and log files. |

| | | |
|---|--|---|
| educational levels. | <ul style="list-style-type: none"> - the technical issues did not hinder the participants' involvement; and - a large majority of the participants including the less experienced in using computers used most of the PDP functionalities. | |
| 2. Participants appreciated this new way of self-organized learning. | <p>Prior to the pilot the participants had a preference for the traditional way of learning and therefore the pilot centred in self-organized learning meant a change in their learning habits. They did not spent much time on personal competence development but:</p> <ul style="list-style-type: none"> - they were very active and used quite often the main elements of the PDP tool; - they enjoyed the possibility to work at their own rhythm, to choose the activities in accordance to their interest s and needs; - they asked to continue self-developing competences at home. | Pre-test, post-test, focus group with participants and observations during and after the pilot support these results. |
| 3. The experience fostered the participants' reflection and self- confidence. | <ul style="list-style-type: none"> - The self-assessment functionality encouraged the participants to reflect on new learning possibilities and on previous experiences. - The participants' felt that they developed social and reflective skills apart from the functional skills more related to the learning resources provided. - The large majority of the participants let the system generate a plan based on their self-assessment and had high expectation with regard to this functionality. - The participants valued positively the potential of controlling their learning progress and being aware of their evolution. - The self-assessment functionality had an effect on the participants' motivation as they realised what things they are able to do. | Supported by post-test, observations, focus groups with participants and experts |
| 4. The participants discovered further competence development opportunities. | <ul style="list-style-type: none"> - The participants found out that they could develop more competences thanks to the competence profile list provided by the PDP tool. - They did not only want to develop a concrete competence available in the system but others they did not think of before the pilot. | Based on the post-tests, observations focus with participants and log files. |
| 5. Recommendations for the improvement of self-organized learning technologies include more interactive and communicative functionalities, feedback and automatic assessment support, and more sophisticated approaches in the recommendation and organization of personal development plans. | <ul style="list-style-type: none"> - The participants had a clear preference for the interactive activities and feedback provision (such as it can be done with LD runtime system). - The users expressed the need to be able to submit assignments and posing questions to experts or other learners. - Some participants also requested to take a test in order to define more objectively the proficiency level in the self-assessment phase. - It is important to provide different ways of organizing activities within personal development plans. - The users expect recommendations based on their personal needs (such as taking into account the proficiency level when suggesting activities). | Observations during and after the pilot, post-tests and focus group with participants lead to these recommendations. |

As a conclusion, the partial results underlying this first finding indicate that neither the little experience in competence-based training and in the use of computer in general nor the technical problems hindered the self-

learning process of the participants. Another partial result supporting this statement indicates that a large majority of the participants, including the less experienced in using computers employed the main elements of the PDP tools quite often in the sessions as evidenced by the [logs], “the description of an activity” (action) was checked an average percentage of 93% of all sessions. Users worked on 2.5 learning activities per session. In the sessions, the users have inspected around 9 competence development plans and added 5 new plans [logs]. Eventually, it was observed that *“All participants asked when the next pilot will be. They want to continue developing competences [observer6-31/10/2008].”*

The second finding highlights that the participants appreciated the self-organized learning concept, nevertheless, they did not spend much time on personal competence development (74% spent between 4 and 8 hours [post-test]). A partial result stressing this conclusion also considers that the participants had to change their learning habits as they were mostly used to a traditional way of learning. Only a 38% of the participants stated before the pilot a preference for searching in the system by themselves what they wanted to learn [pre-test]. However, even if some participants found it difficult at the beginning and needed continuous support by the experts to be able to use the different PDP functionalities, they managed to be more and more autonomous and to appreciate this new way of learning [observations-all]. The participants themselves commented in the [focus-participant] group *“We want to go on... At the beginning, it was hard but now I am starting to enjoy this way of learning.”* In addition, as indicated in [post-test] around 54% enjoyed this way of learning very much and a large majority of 83% wants to continue to develop this competence further in the future. Qualitative results show which elements of the self competence-development training and in this case of the PDP tool were mostly appreciated. For instance, the participants found useful the possibility to work at their own rhythm, to be able to choose activities in accordance to their needs and interests. The [post-test] also indicates that the self-assessment functionality was highly appreciated as 78% of the participants used it for most or all of their competences. Moreover, the appreciation of this way of learning was also observed in the self-training sessions, when a large majority of the participants who have Internet access asked to install the PDP tool at home in order to continue self-developing competences [observations-post, observers-all]. This statement is supported by the [post-test] results indicating that 63% of the participants use the Personal Development Planner at home, which correspond with the percentage of users who have Internet access. Eventually after the pilot experience, the participants still show interest in the PDP tool *“After the end of the pilot, the participants continue asking for the PDP to be installed at home [observations-post].”*

Furthermore, the third major finding refers to the reflection process of the participants and the self-confidence generated by this learning experience. A partial outcome resulting from the quantitative data indicates that the participants learned mainly about reflective skills (40% stated that they have learned much or very much on knowing how to guide their future learning by reflection on current practice [post-test]) as different elements of the PDP tool supported this aspect. A second partial result refers to the self-assessment functionality, which is one of the PDP tool elements that proved to enhance the learners’ reflection process. On one hand 78% of the participants used it for most or all their competences and a large majority of them (88%) let the system generate a plan based on their self-assessment [post-test] and thus had high expectation with regards to this possibility. However, this functionality in the current PDP version is very rudimentary and need to be further developed to guarantee a more detailed planning of the activities taking into account the users’ interest and prior experience. *“After the self-assessment, the participants had high expectations of obtaining a personal plan [focus-experts].” “It promotes autonomy. Participants are their own teacher: create their own plan, self assess... But it would be nice that the generated plan actually takes into account the profile of the participants, i.e. what they already know [focus-experts].”* This statement was also observed during the training session *“One thing to be improved in the system is that it generates a plan in accordance with the self-assessment [observer4-1/10/2008].”* Moreover, the learners themselves underline that the self-assessment element encourage them to reflect on their own learning. *“We find it useful to be able to reflect on our own level of proficiency [focus-participants].”* This has shown to have positive consequences on the participants’ self-confidence as agreed by the pilot experts in the focus group *“...the functionality of self-assessment is motivating for the participants who think they don’t know anything [focus-experts].”* Moreover, another functionality of the PDP tool which promotes the reflection process of the learners is the possibility to mark the activities as completed and have an overview of all the activity history. These elements entail another partial result of the evaluation, which is the control of the learning process and being aware of the participants’ evolution. 86% of the participants evaluated as very useful the possibility to mark activities as completed, only 4% found it useless [post-test]. Participants and experts share these views: *“I find it useful to follow my own personal plan and see the record of my achievements [focus-participants].” “It is motivating for them since they can see their progress [focus-experts].”*

The fourth finding is closely related to the previous one as the reflection process resulting from the use of different elements of the PDP tool also implies the discovery of further competence development opportunities. A partial result supporting this statement shows that the learners found out at an early stage of the self-training sessions that they could develop more competences thanks to the competence profile list provided by PDP tool [post-test]". The [logs] files also support this result by indicating that the list of personal development plans was inspected in 67% of all sessions and that the description of "competence profiles" was inspected an average percentage of 90% of all sessions. This statement was also observed in the training sessions *"It happened that a group of learners who registered to develop English competences also decided that they would learn about ICT when they found out about that opportunity [observer2-06/10/2008]"*. Moreover, it was observed that the majority of the participants discovered what things they could learn and/or improve in the future [observations-post] and felt motivated by this opportunity. As the participants stated in the focus group *"It is fabulous, it opens the door to different learning possibilities..."*; *"It enabled us to discover more training opportunities (...)"* *"We want more competence profiles in the PDP tool"* [focus-participants]. In addition, the great majority not only wanted to continue developing a concrete competence in the future but also other competences that they did not think of before starting the self-training. *"A participant who completed all the activities related to the PowerPoint competence profile found out that she wanted to learn how to add sound on her presentation and how to send it by email [observer2-06/10/2008]."*

Last but not least, the fifth finding points out the different recommendations emerging from the pilot experience and which would contribute to the improvement of self-organized learning technologies. One of participants' main remarks resulting from the self-training experience is their preference for the interactive activities which allow them to perform the activities directly on the system and to receive a feedback on their actions. This need is perceived by all the pilot actors. *"Regarding the activities on a PDF format, the participants ask for the possibility to fill in directly their answers [observer5-25/09/2008]."* *"They do not like to have to write down on a separate sheet the answers to an exercise and thereafter checking the answers in the solution part [observer6-26/09/2008]."* *"I prefer when the activities are interactive [focus-participants]."* The [post-test] also suggest this conclusion as 16 out of the 18 participants using the ICT activities run by the LD runtime system had a preference for the interactive guidance provided by this tool. Moreover, another recommendation is the existence of a facility within the tool that allows submitting assignments and posing questions to other learners or experts. This need was observed by the participants in the focus group *"Comments or advice of other participants of how to use the tool would also help us to use it"* and *"When using the PDP at home, the blog might be used to resolve doubts".* [focus-participants]"and also after the completion of the pilot *"Participants mentioned another utility the blog may have. Some participants indicated the need to use a chat to be able to pose technical or content-based questions to a specialist [observations-post]."*

Furthermore, the evaluation results stressed the importance in the definition of the self-assessment tool functionalities. In this sense, some participants requested an additional element enabling a prior test in order to define more objectively their proficiency level (e.g., taking a test in the self assessment phase). As a participant mentioned *"a more objective evaluation is also needed..."* [focus-participants]." In addition, the participants had high expectation with regards to the recommendations generated by the system based on their prior experience and personal needs. As observed in a self-training session, *"One thing to be improved in the system is that it generates a plan in accordance with the self-assessment [observer6-26/09/2008]."* This statement was supported by the users view *"After the self-assessment, participants had high expectation of obtaining a personalized plan [focus-experts]."* The high percentage of participants (88%) who let the system generate a plan based on their proficiency levels also reflects this need [post-test]." Eventually, the importance of providing different ways of organizing activities within the personal development plans in the performance tab of the PDP tool was also mentioned by all the pilot actors. *"We experienced difficulties in the "perform tab" as the activities listed have no real meaning between them. The participants were expected that the activities generated would be logically linked together (in a certain order, such as alphabetically, or category, such as by competence). Another organization of the plan is necessary [observer1-15/10/2008]."* *"There should be an index [focus-participants]."* *"The participants ask each other where to find the activities with audio as they are not ordered in a specific way [observer3-15/10/2008]."*

Conclusion

This paper has presented a pilot study that investigates the benefits of the TENCompetence infrastructure for supporting competence development in the Àgora non-formal context where learners have low educational levels. More than 100 pilot participants used the TENCompetence PDP tool to create and perform their personal

developments plans associated to competences profiles for social inclusion. The results of the pilot are very encouraging for the research domain for self-organized/self-directed learning technologies and for the enhanced support of lifelong learning situations involving people with low educational profiles.

The pilot has shown that the TENCompetence infrastructure can be successfully applied in the challenging context of Àgora. Contrary to our expectations, it turned out that the participants, even if they did not have the necessary computer skills or planning skills beforehand, were able to acquire and use these skills, and enjoyed this. The PDP offered participants a new way of learning which fostered their self-organization and increased their motivation. The tool made participants discover competence development opportunities, what which led them to create several competence development plans associated to different profiles of competences. The pilot meant a relevant change in the Àgora context. It was observed how participants' confidence to take the responsibility for the planning and performance of learning activities increased along the pilot. Moreover, the PDP support for goal setting, self-assessment and progress control was seen as particularly positive for promoting participants' reflection and awareness of their own learning. It was this change not only in abilities, but also in mindset that enabled participants to continue their activities in the pilot, despite the technical and other problems that they experienced. Their reward was large, not only and not primarily by what they actually learned, but by discovering a world of further competence development opportunities that was opened up for them.

The main requirements for future learning technology developments that emerge from the pilot include improving the support for feedback and competence assessment, offering further functionalities for communication and knowledge sharing, and providing advanced approaches (within the PDP) for the recommendation and visualization of learning paths. The TENCompetence project is already working towards providing solutions for these requirements. Its outcomes will be applied and tested in Àgora next year. Àgora participants are really looking forward to the new pilot.

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Lifelong Learning Organisers: Requirements for tools for supporting episodic and semantic learning

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ABSTRACT

We propose Lifelong Learning Organisers (LLOs) as tools to support the capturing, organisation and retrieval of personal learning experiences, resources and notes, over a range of learning topics, at different times and places. The paper discusses general requirements for the design of LLOs based on findings from a diary-based study of everyday learning practice; and also based on the design and evaluation of KLeOS, a prototype LLO that supports learning projects, episodes and activities through the linking of learning content with semantic and episodic context. We suggest that LLOs should assist in capturing both the episodic and the semantic aspects of learning events, and should incorporate retrieval mechanisms that utilise both types of memory (i.e. episodic and semantic) to assist tracing back knowledge and resources. Issues for future research on LLOs are also discussed.

Keywords

Lifelong Learning Organisers, activity-based interface, continuous archival and retrieval of personal learning, episodic and semantic memory, concept maps, timelines, personal learning environment

Introduction

Traditional conceptions of learning as a classroom-based activity are expanding to recognize the value of informal, self-directed learning. Learning surveys carried out since the 1970s (Livingstone 2000; 2001; Tough 1971) consistently show that a large proportion of learning takes place outside educational institutions and pertains to the learner's personal interests and everyday life demands. Recently in the UK the Department for Innovation, Universities and Skills (DIUS) launched a consultation into the development of a government strategy for adult informal learning in the 21st Century, endorsing the value of informal learning for the well-being and prosperity of society and its citizens. One of the themes addressed in the consultation process is concerned with how we can improve the connectivity between different kinds of learning episodes (DIUS 2008). This paper is concerned with the design of tools to support adults in consolidating personal learning experiences across contexts through capturing, inter-relating, organising and retrieving learning events, associated learning resources, and the knowledge and skills learned *en route*. These we call Lifelong Learning Organisers (LLOs), defined as systems that assist learners in organising learning activities, episodes and projects, the knowledge they learn, and the resources they use, over a range of learning topics, at different times and places, in ways that integrate their learning experiences to create personal, meaningful records of their learning over a lifetime. LLOs are thus valuable cognitive as well as practical tools for the self-organised learner.

LLOs as cognitive tools are underpinned by constructivist conceptions of learning (Bruner 1960), which maintain that meaning is constructed by the learner through the association and integration of the new information with what they already know. Learning is dependent on the learner's interpretation of experience, which results in the assimilation and accommodation of new information within previous learnt knowledge structures. By providing the means to capture experience, the knowledge gained from it, and the associations between aspects of the experience and knowledge gains as well as between different experiences, LLOs can assist reflection and consolidation of experience and knowledge.

LLOs as practical tools build upon the everyday learning practices of archiving and reviewing learning materials. Archiving of personal notes, paper-based and electronic documents, emails and other types of material is common practice amongst learners of all levels and ages. Personal methods for archiving learning can vary from maintaining an elaborate archiving system with an underlying categorisation hierarchy accompanied by systematic, neat note-

taking, to ‘messy’ piles of documents on a desktop complemented by sticky notes. Studies of memory and learning suggest that recording and archiving activities (e.g. note taking) may assist a number of cognitive processes involved in learning, such as the encoding and storage of information (see for example Kobayashi 2006). For example, the value of revisiting experiences to evaluate and improve performance is an essential part of modern sports training: a coach will often review a video record of an athlete’s performance to reflect with the athlete on how to improve techniques and overcome weaknesses. LLOs support and extend the archival and retrieval of personal experiences to all areas of personal learning.

LLOs provide a means to capture the structure of learning and how it relates to the learnt knowledge. These make up the episodic and semantic parts of a learning event respectively. The terms episodic and semantic are used here in the same sense as in Tulving’s (1983) memory model: episodic memory is involved in the recording and subsequent retrieval of memories of personal happenings and doings, while semantic memory is the store of general facts and knowledge of the world that is independent of a person’s identity and past. At least one type of memory is consulted in knowledge retrieval.

This allows us to make a distinction between episodic and semantic learning context. Episodic context consists of the practical specifics of a learning experience (information about when, where, with whom, and how we practice learning). Semantic context consists of the scaffold that accommodates the gist of our learning experiences (the web of associations between terms and concepts that allows the newly learned to ‘slot into’ what we already knew). Recollections of episodic context are used in re-establishing the sequence of learning activity from a personal perspective, and recollections of semantic context are used to put the knowledge gained in one context to use in another context.

This distinction can be useful in analysing learning context as an instrument for organising learning experiences, resources and content, and utilising them to re-establish the structure and content of prior learning. Tools for utilising and supporting episodic context include diaries, planners, and personal organisers (episodic organisers). Tools for the development and organisation of external representations of semantic context include concept maps and note books (semantic organisers). LLOs provide a combination of both types of tool, allowing people to capture and retrieve their learning episodes and also their related, interconnected knowledge. They achieve this by utilising external representations of semantic and episodic context to enable the learner to easily capture episodic learning and to couple it to the scaffold of concepts and associations that constitutes semantic learning. The LLO presents these linked representations back to the learner upon request for reflection and reuse.

Applications of concepts for capturing and indexing everyday life events and thoughts range from Vannevar Bush’s MEMEX (Bush 1945) to the more recent MyLifeBits project at Microsoft (Gemmell *et al.* 2002), the Memories for Life UK Grand Challenge (Fitzgibbon & Reiter 2003), and the Learning for Life UK Grand Challenge (Taylor *et al.* 2006). Placed in this context, the paper seeks to inspire research and development work in LLOs through suggesting an initial list of general requirements for LLOs. The methods used to elicit the requirements are described. These included a ‘diary: diary-interview’ study of personal learning episodes; and the design and evaluation of a prototype LLO called KLeOS. A gradual presentation of the resulting requirements follows, starting with those emerging from the diary study and continuing with those that emerged from the evaluations of KLeOS. The paper concludes with a discussion of future research issues for the design of LLOs.

Methodology and methods

The work reported here followed the Socio-Cognitive Engineering (SCE) approach (Sharples *et al.* 2002). SCE is a coherent approach to describing and analysing the complex interactions between people and technology, so as to inform the design of socio-technical systems (technology in its social and organisational context), while paying attention to the transformations to practice brought about by the introduction of the new technology (Taylor *et al.* 2006). SCE has two stages: an analysis stage and a design stage. Analysis involves an investigation into how activities are performed in their normal contexts on one hand, and a theory-based study of the underlying cognitive and social processes on the other. These lead to the definition of a task model that provides a structured account of how the activities are currently performed, the people involved, their contexts, the tools and technologies they employ, the structure of the tasks and an account of their cognitive processes, management of knowledge, and social interactions. In the design stage, the task model acts as the basis for the development of a design concept, which is

used to generate a space of possible system designs. This process leads to the specification of the functional and non-functional aspects of the system, and concludes with implementation. SCE affords further iterations, whereby the transformations to patterns of work and social interaction brought about by the new system become contexts for further analysis and design. We report here the outcomes of the first iteration of SCE to the design of LLOs.

The analysis stage consisted of a diary-based study of the everyday learning practice of 12 individuals. The study has borrowed techniques from qualitative research to produce a data-grounded and theory-informed descriptive Framework of Lifelong Learning (Vavoula 2004), which identifies core concepts and patterns in the practice of everyday learning, and which corresponds to the task model. The framework was analysed further to infer general requirements for lifelong learning support systems.

The design stage involved the specification of a design framework based on the requirements produced in the first part; and the specification (by design and implementation) of a solution to match the design framework. The outcome was the prototype system KLeOS (Knowledge and Learning Organisation System), a system that enables the user to perform and organise learning activities, episodes and projects, and to associate them with the notes they make of the knowledge and skills learned in the process, over a lifetime. The analysis and evaluation of the prototype (through a controlled learning task with a group of 14 users) have led to the refinement and extension of the original requirements to specify requirements for a particular class of lifelong learning support tool, which we have named Lifelong Learning Organisers.

Studying the learning practice: general requirements for LLOs

The study of everyday learning practice used the “diary: diary-interview” method (Zimmerman & Wieder 1977) for data collection and an adaptation of Grounded Theory (Glaser & Strauss 1967) for data analysis. Twelve adults participated, of ages between early twenties and late forties. Six of them were postgraduate students, one was an undergraduate student, one was a lecturer, two were university secretarial/technical staff, one was a school careers advisor, and one was a researcher. The participants were asked to keep a diary of their everyday learning events over a period of four days, making notes of their physical and social context, the activities they performed, the resources they used, and the problems they were faced with. This was followed by semi-structured interviews lasting on average one and a half hours that focused on the participants’ logged data and on their learning practices in general.

The received entries varied in nature from classroom-based learning, to lab-based collaboration, and everyday life problem-solving (e.g. learning how to send flowers through Interflora). Detailed results can be found in Vavoula (2004); an overview of the collected data and methods can be accessed online at <http://www.eee.bham.ac.uk/vavoula/PhD/FieldStudies.htm>. The data was analysed following the principles of Grounded Theory, using the constant comparative method for qualitative analysis (Glaser & Strauss 1967). The outcome of the analysis has been a descriptive Framework of Lifelong Learning that identifies core concepts and categories in the process of everyday learning. The development of the framework involved a 4-step analysis of the diary and interview data. In step 1 the diary and interview data were segmented into extracts. For the diary, the segmentation was performed based on the distinct learning experiences described by the participants. For the interview, the segmentation was based on the identification of points in the dialogue where a shift of focus occurred. In step 2, extracts were summarised and tagged with topic indicators. In step 3, the topic narratives were recapitulated and associated with emerging issues. In step 4, concepts and categories related to the issues were identified. Table 1 illustrates the analysis process and the progression from raw data to concepts and categories of the framework. It depicts only a part of the framework related to note-taking.

Table 1: Example of the process of analysis, from diary-interview data to categories of Framework of Lifelong Learning

| | |
|---|--|
| Diary & Interview Extracts 3A, 3U, 3T | Diary: “-Do you use a notebook? For what kind of notes? - Yes. Notebook 1: for personal reminders, e.g. train times, shopping lists. Notebook 2: academic work, e.g. notes from meetings with supervisors.” |
| | Interview: “...I would write [in my diary] something that I've learned, that I need the 5:15 train, it's not as learning orientated as my academic notebook which I will miss not having if I, you know, was at a supervision... But [the academic notebook is] not something that I would carry around with me for my great thoughts.” |
| | Interview: “The little notebook is in my bag most of the time. And I will use that for recording general |

| | |
|-----------------------|---|
| | <p>information like train times or for lists of what I need to go shopping for, who I'm going to send Christmas cards to, the general no-work-related. The academic notebook is a big A4 book that usually sits on my desk in the office, it very rarely comes home with me ... in which I keep track of progress purely related to work. And it's a combination of things to do, things to read and what I'm interested in doing myself, my thoughts on [...] [There is] very little overlap. There might be an overlap when somebody gives me a phone number or something and I don't have my [diary] [...] it has happened that I give them my notebook for them to write it in and then I'll transfer it to my diary, so it's duplicating like that. The notebook doesn't tend to have dates of things to do in it. It has goals to be achieved. [...] If I looked for a specific train time then I will put it in my diary "getting 5:15 to London". And it will go straight into the diary. If I have train times for getting from University into town as general train times, which are in my other notebook. And I keep on referring to that [...] So it would be more general."</p> |
| Topic 3S | <ul style="list-style-type: none"> • One notebook for academic work. Notes down things about supervision meetings, like what supervisors think should be doing next and their comments. Keeps in it track of work-related progress – a combination of things to do, things to read, thoughts, personal interests. • Academic work notebook is big A4 book that stays on desk. Always takes it with her at meetings, and rarely at home. • Also has 'little notebook' for general things. Carries it in her bag most of the time. Records in there general information (shopping lists, Christmas cards lists, general non-work-related information). |
| Concepts & Categories | <p>Category: Learning Activities Sub-category: Note-taking Concepts (italics indicate those related to Issue 3C):</p> <ul style="list-style-type: none"> Timing (during/after activity) Content, structure and format of notes Types of content (thoughts, general information, references, to-do items, reminders) Structure of content (by recording device, by physical proximity of related items, by temporal sequence) Adequacy of notes Ownership Notes recording devices Utility of notes |

In brief, the Framework of Lifelong Learning describes learning practices in terms of: the learner; the hierarchical organisation of learning into projects, episodes and activities; the learning objects that are used, manipulated, organised, archived and retrieved during learning; the outcomes of the learning process; the breakdowns that occur because of, or during the learning process, or which are the cause of learning; and the social, physical and personal contexts of learning.

The Framework of Lifelong Learning was further analysed to draw out general requirements for lifelong learning support systems. This process involved re-examining the framework as one that describes a practice of learning in which an imagined tool to support the learning process is always available. At the time of producing the requirements this learning tool was thought of as a generic "black box": any explicit or implicit references in the framework to any form of support that the learner actually receives, could receive, or wishes to receive during learning were attributed to that tool without assuming or specifying anything about the tool's form or structure. The process resulted in an indicative set of general requirements under six main categories. A title, justification (founded on the explicit/implicit references to support in the framework) and specifics (detailing the requirement) of each category are given below:

1. Title: Assist the organisation of learning into projects, episodes and activities.

Justification: The learning practice is organised into three levels of granularity. At the finest level, the learner performs learning activities (such as reading, discussing, reflecting, and making notes). These are grouped together in a middle level by thematic, temporal and/or spatial proximity of context to form learning episodes (i.e. time-delimited learning events). At the coarsest level, learning projects are formed as collections of (past and future) episodes that exhibit some contingency in terms of purposes and/or outcomes. This organisation may

be intentionally designed into the learning practice (for example when the learner structures their learning by setting goals and objectives, and planning a route through a physical or conceptual learning space). Or it may emerge from the learning practice (for example when the learner dwells on everyday tasks and activities that have learning side effects, which are reflectively organised into learning projects).

Specifics: Assist learners to (a) plan and manage learning projects, (b) organise and complete learning episodes for their projects, and (c) perform common learning activities during their learning episodes.

2. **Title:** Adapt functionality to suit learner characteristics.

Justification: A learner has certain physical characteristics (and thereby physical abilities or disabilities), assumes a number of social roles (a colleague, a friend, a parent, etc.) and has a number of characteristics that relate to how (s)he practises learning (cognitive styles, learning tactics, preferences, etc.). Some of these may change with time; and they all influence the learner's planning of projects, experience of episodes, and performance of activities.

Specifics: The system should gather information on (long-term and short-term) learner characteristics and adapt its functionality appropriately.

3. **Title:** Support the learner's communications and collaboration with other people.

Justification: While learning can be a solitary experience, other people are often involved in learning episodes (53% of the episodes reported involved other people: co-learners, teachers, colleagues, or strangers). Communications vary in terms of synchronicity, media used, structure and degree of formality, and roles adopted by the participants. Collaboration involves the (co-)construction and sharing of objects, resources and conceptualisations. Common problems with communications and interactions with other people include identification of the right person to involve, availability and willingness to participate, and cultural discrepancies.

Specifics: The system should support the learner at all phases of communicating and learning with other people, including identifying and selecting appropriate people to learn with/from (e.g. by monitoring previous learner evaluation of their helpfulness, recommendations, etc.), establishing a communication channel, and exchanging effective representations of understandings irrespective of background differences.

4. **Title:** Support the learner in problem solving.

Justification: Only a third of the reported episodes happened without any problems. For the rest the learners reported problems relating to time management or to the learning objects used, and also emotional, physical and learner-specific problems. Problems can interrupt or initiate the learning process, as sometimes learning is the means to solve a problem which may have originated in an area of life that is not associated with a learning project (e.g. figuring out how to fix a broken piece of home machinery).

Specifics: Support the user in dealing with problems whether these problems come about in the course of learning, or are the object of learning.

5. **Title:** Assist in the use of learning objects.

Justification: Learners interact with objects that can support learning, such as information resources and memory aids, as well as with conceptual 'objects' like thoughts, ideas and understandings. Objects are discovered, assessed for suitability, accessed, manipulated, evaluated, archived, stored (or disposed of), and re-used or referenced.

Specifics: Assist in the use of physical, tangible objects, such as a piece of machinery; as well as of non-physical, intangible objects, such as reflections, by enabling the construction of a material representation of these objects. Assist the learner in all phases of an object's lifecycle: discover and identify what is suitable for the task at hand, get access to it, use it, evaluate it, and store, organise or dispose of it depending on its assessed utility. Assist the user to re-discover previously used objects.

6. **Title:** Adapt functionality to suit the context of learning.

Justification: Learning context consists of the time and timing of learning; the physical and social settings; the resources, information and learning topic; the learner status and objectives; and its connections with other instances of learning. The instantiation of these elements in each learning episode influence the learning practice. For example, the availability (or lack of) certain resources and people, the structure and hierarchy of the social setting, the learner's objectives and previous knowledge, all influence how learning will take place in terms of selected activities, the way they are carried out, and their outcomes. Knowing the context of learning leads to better support, tailored to the learner's needs at any time.

Specifics: Monitor the elements of the context of learning and how it evolves in the process of learning, so as to be able to provide context-specific support.

The first of the six top-level requirements (assist the organisation of learning into projects, episodes and activities) formed the backbone of the design framework for the second stage of SCE, leading to the conceptualisation of the intended system as a Lifelong Learning Organiser. Based on the design framework, the general requirements were re-interpreted into elements of a design solution. Table 2 presents the progression from requirements, to design framework, to elements of the design solution.

It should be noted here that the process of re-interpreting requirements into a design solution is not univocal. General requirements specified the type of learning tool (i.e. LLO) but not the specific form it would assume: the interface, the interaction components, how data is presented to and requested from the user. The conception of the details of the form in the shape of design solution elements brings up another level of functionality, relating to the specifics of the form rather than the purposes it serves. It was not possible to specify this functionality through an *a priori* study of the learning practice and was thus stipulated at design time. Thus, in addition to the requirements that transpired through the analysis of the diary study, additional requirements emerged through the new possibilities identified in the conception of the design solution.

The second stage of SCE proceeded with the design of a prototype LLO called KLeOS (Knowledge and Learning Organisation System). Evaluations of the prototype reinforced the requirements captured at design time. Moreover, reflecting on the users' perceptions of the system during the evaluation, has led to the formulation of additional requirements for LLOs. The design of KLeOS, its evaluation and the additional requirements that emerged from these exercises, will be present in the following section.

Additional requirements emerging from the evaluation of a prototype LLO

KLeOS: A Knowledge and Learning Organisation System

KLeOS supports the organisation of learning experiences, resources and knowledge over a lifetime. It allows the monitoring of learning projects, the organisation of learning episodes, and the performance of learning activities; while at the same time it enables the capturing of the learned knowledge by facilitating note taking during and after the learning episode via a basic concept mapping tool. A bridge is formed between the captured episode data and the learner's notes by tagging the notes with information about the related activities, episode and project; and by linking the activities with the related notes. The captured episode data, the notes, and the links between them are utilised in the retrieval of past knowledge and learning.

Table 2: From requirements to design framework to design solution elements

| Requirement | Design framework | Design solution elements |
|--|--|---|
| 1. Assist the carrying out of learning projects (including planning, assessing and evaluating, as well as related serendipitous learning); support the user's learning episodes; assist the performance of learning activities | Organise and structure the performance of lifelong learning | <ul style="list-style-type: none"> • Provide a timeline representation of projects indicating start, end, priority, topic, objectives, relevant episodes • Provide integrated environment for performing episode, optionally matching episode to project, monitoring episode location, people, objects and other context features, relevant activities • Within the episode environment, provide tools for the manipulation of learning objects and the performance of learning activities |
| 2: Adapt functionality to suit learner characteristics | Accommodate learner preferences (e.g. for tools or methods) and objectives | <ul style="list-style-type: none"> • Allow learner to use favourite tools and styles for carrying out activities (e.g. favourite word processor, note taking style, etc.) • Aid learner to summarise and review progress |
| 3: Support the learner's communication and collaboration with other people | Consider communications as a form of learning object | <ul style="list-style-type: none"> • Support communication as a learning activity |
| 4: Support the learner in | Offer the means to review | <ul style="list-style-type: none"> • Support the learner to retrieve and review |

| problem solving | past practice in problem solving | previous learning |
|---|--|---|
| 5: Assist in the use and organization of learning objects | The use of learning objects is central to the performance of learning activities, and the organisation of learning objects is a central function for a learning organiser system | <ul style="list-style-type: none"> • Organise digital learning objects by context of use, associate objects with relevant learning events and with relevant knowledge |
| 6: Adapt functionality to suit learning context, by monitoring and reflecting on: time information, the physical setting, the social setting, learning objects, information accessed for later retrieval, knowledge gain, practical outcomes and reflections, and the learning activities performed during a learning event | Context plays an important role in organising learning, since it is by spatial, temporal and thematic context proximity that learning activities, episodes and projects are grouped together | <ul style="list-style-type: none"> • Time-tag learning projects, episodes and activities • Location-tag learning projects, episodes, and activities • Track the presence of other people during episodes • Track the use of learning objects within activities • Store learning objects with their contents • Concentrate on knowledge gain: use concept maps to allow learner to record and maintain their knowledge gains over learning episodes and activities • Provide a timeline representation of activities within episode indicating start, end, type of activity, and matching to relevant objects and knowledge |

Figure 1 presents the main components of the system: (a) the projects and episodes timeline component, (b) the activity performance, capture and retrieval component, and (c) the concept map-based note-taking component. Component (a) utilises the timeline metaphor (Plaisant *et al.* 1998; Plaisant *et al.* 1999) to represent information about learning projects and episodes. A timeline affords traversing time backwards and forwards, and zooming to change the detail of time shown (for example, hourly, daily, monthly, yearly, etc. views). In KLeOS, projects are represented as lines in a project lines area, parallel to a timeline, and related episodes appear as vertical marks on the respective project line at appropriate time locations (for details see Figure 2).

Component (b) offers a learning environment where the user can perform learning activities (such as reading, writing, discussing and searching), where each activity is associated with a learning episode (and consequently a learning project) and involves the use of learning objects ('document') and the creation of notes about what is being learnt. While the learner uses this learning environment, the system is capturing the performance of activities, the associated documents used, and the created notes. The learning environment thus consists of buttons to invoke different activities and select the document to work with; a document area; a documents list; a notes list; and a timeline of activities performed within the current episode (for details see Figure 3). These lists are updated automatically as information is recorded while the user proceeds with their learning, reading different documents and making notes.

Note-taking is served by component (c), which enables users to make notes of the knowledge they gain on a Basic Concept Mapping Tool (see Figure 4). Concepts are recorded as chunks of text in a box (node) and are placed on a 2-D map at a location decided by the user. Relationships between concepts are captured as labelled links between the nodes, and both nodes and the links between them can be edited / deleted. Nodes may be added to the map whilst the user is undertaking a new, or revisiting a past activity. When creating a new node in the map, information about that activity is stored along with the node itself, and this information is maintained when the user later edits that node during subsequent activities.

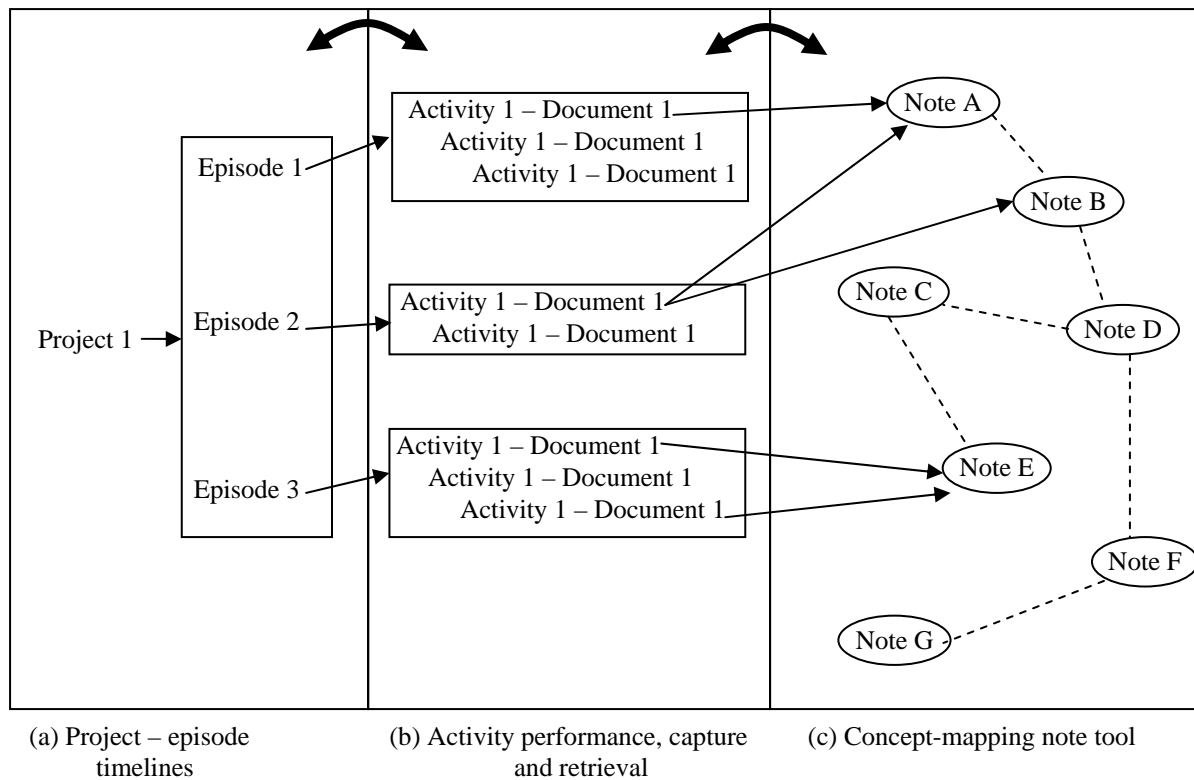


Figure 1: KLeOS structure

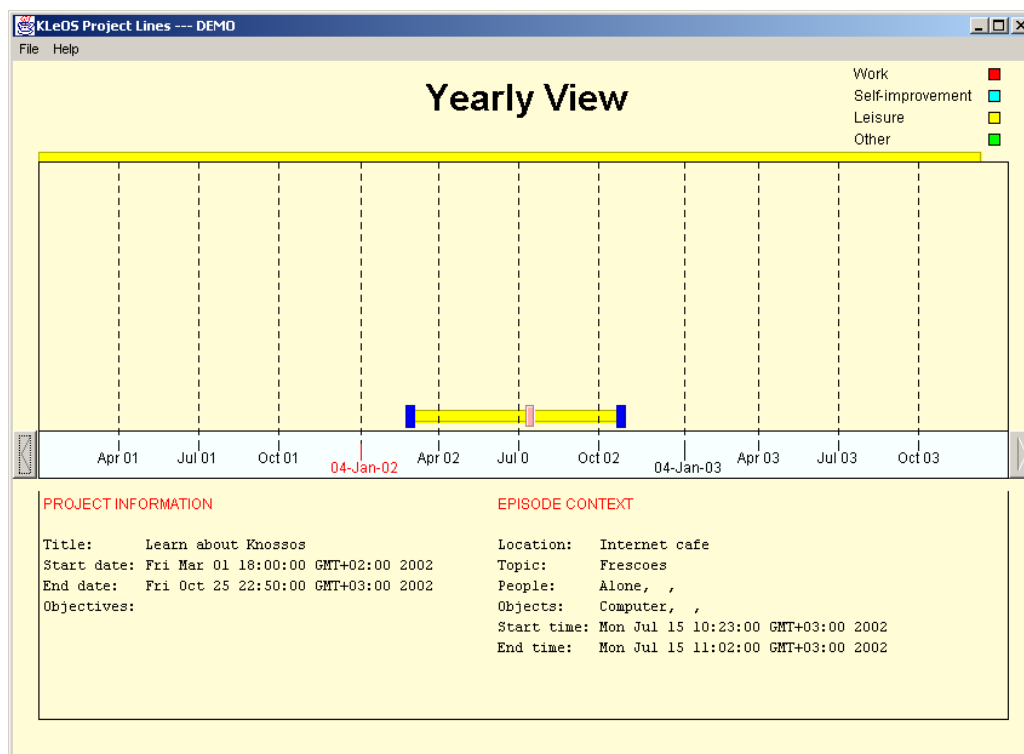


Figure 2: Project Timelines

KLeOS provides a bridge between the practice of learning (activity-episode-project hierarchy) and the external representation of the cognitive outcomes of learning (concept map), by automatically associating a note with the

activity context in which it was created. Thus, nodes in the concept map are tagged with information about the learning activity the user was performing at the time of note-taking; while each learning activity is annotated with a list of notes created in the concept map during the activity. The user can thus review previously recorded projects, episodes, activities, documents and notes. Retrieval can start either at the projects-episodes timeline, which the user can transverse until they locate the related episode and bring up its activity performance context (i.e. component b); or it can start in the concept map which the user visually explores to locate related notes and from there trace back the activity-episode context during which that note was made, review the relevant document, see the list of relevant notes, and perhaps from there jump to a different part of the concept map.

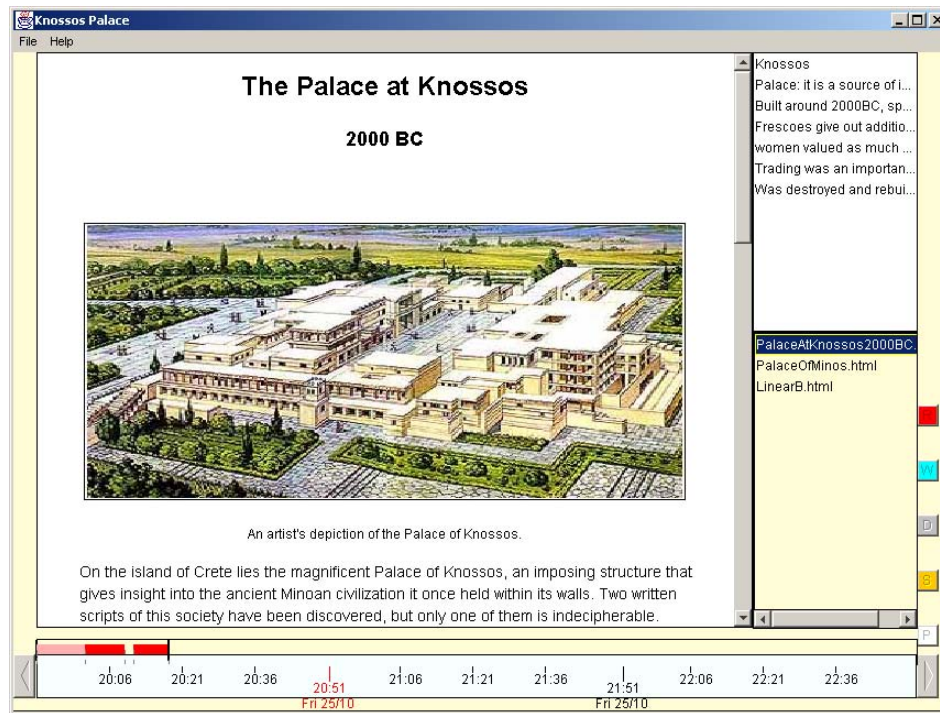


Figure 3: Capturing learning in KLeOS

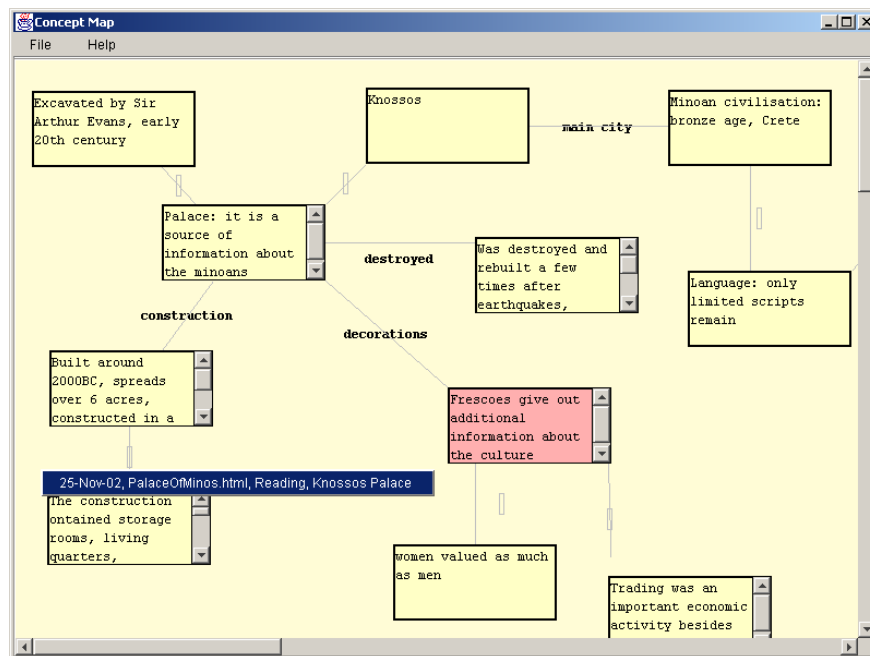


Figure 4: Basic Concept Mapping Tool

Evaluation of KLeOS

Product Reaction Cards

We assessed the overall user acceptance and desirability of the system using Product Reaction Cards, which are part of the Desirability Toolkit and provide a way of measuring intangible aspects of the user experience quickly and easily in the lab (Benedek & Miner 2002). Participants are given 118 cards with words or short phrases printed on them. The set contains 60% positive and 40% negative/neutral cards. The participants are asked to start by going through all the cards and selecting those they think best describe the system, or how they felt while using it. The cards they have selected are then recorded and participants are asked to select the five they think contain the most representative descriptions and justify their choices.

Fourteen postgraduate students/researchers with an interest in educational technology and of varying backgrounds (computer science, psychology, engineering, management, literature) took part in the evaluation. More than half the participants shortlisted the cards ‘usable’, ‘understandable’, ‘useful’, ‘organized’, ‘helpful’, ‘effective’, ‘easy to use’, ‘straight forward’, ‘time-saving’, ‘novel’, ‘engaging’ and ‘clear’. More than half the participants also found the system ‘slow’, referring to instabilities of the current implementation rather than the LLO concept itself.

The general concept seems to have induced positive feelings in the users, with a number of them indicating that they consider it a valuable learning tool:

“Memory is extremely important and improving ways in which information can be acquired, stored and retrieved are increasingly necessary as the complexity of subjects rises. Students complain about not being able to use their time effectively, I think that, with a few refinements, this sort of tool could be extremely useful” (male, 28, research student),

“I felt it would be a very valuable resource, in terms of helping me organise a large body of information” (female, 26, research student),

“I liked the fact it was my personal record, I could see when I looked at a document, the notes I’d made and how I felt these notes related to other ideas. I felt a certain sense of ownership which was reassuring.” (female, 34, research student).

Usability Evaluations

KLeOS features were evaluated via a questionnaire for their perceived usefulness, appeal, and utility as learning recall aids, following a 60-minute lab-based learning task and a follow-up revision session two weeks later. The Basic Concept Mapping Tool, Notes List, and the individual episodes recorded for each project were voted as most useful; the Activity Lines and the ability to pause learning were thought the least useful.

The list of features that the participants were asked to rate with regard to their utility as learning recall aids also included the participant’s own memory as a comparison measure. The Documents List and the Concept Map scored better than the participants’ own memory, indicating that the participants regarded the collections of their learning documents and their notes as significant recall aids – this is not surprising, given the extent of archival of learning objects and personal notes learners usually do. The Concepts List did not score as high although it was identified as a useful feature. The Activity Timelines were not thought to be of help as recall aids, which may be an indication against the presumed linearity in the performance of learning activities.

The most appealing features were the Basic Concept Mapping Tool, followed by the linking between documents, activities and relevant notes, and the Documents List. Attributes of the software such as its novelty, ease of use and simplicity were also mentioned. The least likeable features related mostly to aspects of the interface (like limited navigation and manipulation of concept map objects, the colours, shapes and general appearance of the interface, the slowness of screen refreshing, etc.).

Overall, the concept of KLeOS was well received, with 13 participants stating that they liked/appreciated the idea, and only one expressing a negative opinion. The perceived greatest advantages of the system were (a) the ability to keep a record of one's learning and revisit that record (mentioned seven times), (b) the ability to organise learning resources, knowledge, and relationships between them (mentioned six times), and (c) the simple and easy to use interface (mentioned three times). The perceived greatest disadvantages were (a) that it is time consuming to maintain, (b) it is not flexible enough (e.g. to accommodate learning material outside the computer), (c) the interface performance, (d) the lack of integration with other tools / technologies, (e) the lack of a text search facility, (f) the dependence on (generally unreliable) electronic devices, and (g) the danger of potentially reducing the amount of note-taking one does.

Additional requirements for LLOs

Reflecting on the design and evaluation of KLeOS, a number of additional requirements emerged. Table 3 lists these requirements and demonstrates how they relate to the design and evaluation findings.

Table 3: Additional requirements that emerged from reflections on KLeOS's design and evaluation findings

| Requirement | Evaluation findings | Reflections on design |
|---|---|--|
| 7. 'Sense' contextual information (e.g. continuous activity, topic/objectives contingency, fixed location, people, resources, location, and time) to automate as much of the monitoring as possible (e.g. automatic generation of project-episode-activity hierarchies), and thus keep maintenance times low. | a. High maintenance time | b. User should be able to start learning activities quickly, without the need to provide too many contextual details |
| 8. Support all commonly performed learning activities (note-taking, discussions, problem solving and breakdown recovery, searching for information, receiving and providing help, reading, writing, reflection, planning and prioritisation). | | a. The whole range of learning activities identified in the study must be supported |
| 9. Adjust to user preferences by allowing the user to: 10. negotiate the level of granularity for the activities (e.g. an activity may consist of the processing of a single object or multiple objects, or the manipulation of a single object may be broken down into more than one activity) 11. work with their preferred (external) tools/applications 12. select their preferred representations for their sets of notes and documents (e.g. concept maps or linear text); and for their sets of activities, episodes and projects (e.g. timelines or calendars) | a. Lack of integration with other tools | b. Learner must have choice over interface metaphors (e.g. timelines) and external representations for notes/documents, based on personal styles |

| | | |
|--|--|--|
| 13. Provide search facilities that draw on both episodic and semantic memory, and on combinations of the two | a. Lack of text search | b. Learner must have other search options in addition to browsing-style exploration of past learning episodes and learned concepts |
| 14. Implement on reliable technology with a ubiquitous user interface | a. Depends on reliability of digital technology b. Slow | c. Learner must be able to perform activities outside a specific application |

An ideal LLO

The requirements discussed in the previous sections have helped us to create a vision for an ideal Lifelong Learning Organiser as a system that observes episodic learning context and how it is coupled with the scaffold of concepts and associations that constitutes the semantic learning context; creates records of it; and presents it back to the learner upon request for reflection and reuse. The ideal LLO is conceived as an alternative or add-on to the computer 'desktop' metaphor. Instead of (or as well as) associating electronic objects and documents with locations in folder hierarchies, the LLO associates them with the activity contexts in which they are used or created. The launching of applications used for various activities happens automatically, based on user-established associations between activities and applications. For example, a writing activity will launch Microsoft Word™, OpenOffice.org Writer™, or Windows® Notepad, depending on designated user preferences.

In the course of performing learning activities the person learns concepts and facts, and forms mental relations between them as well as relations to other pieces of knowledge that had been acquired in the past. In everyday life, these are often recorded as notes in various forms: concept maps, linear text, diagrams, document annotations such as highlighting, etc. To maximise the LLO's functionality, once encountering a new concept the learner would make a note about it. The LLO, by applying automatic text processing techniques can identify the topic of the learning and retrieve a relevant notes document. The learner is able to form links between different portions of the notes document as well as across documents to represent knowledge interconnections. The LLO could also automatically linearise a network of notes, presenting its semantic associations as narrative text, based not on the order in which the notes were taken, but on the strongest chain of semantic associations between them (see Sharples *et al.* 1994 for an algorithm to automatically linearise notes networks).

The monitoring and recording is transparent, taking place in the background: the system does not interfere with the learning, nor does it force the learner to diverge from their learning 'rituals'. Rather, it is silently taking note of what happens. In its simplest form, the LLO logs what activities the learner selects, the objects they manipulate, any notes made during the activity, and the location and time of learning (e.g. employing positioning systems and time-stamps). A more advanced system will additionally employ artificial intelligence techniques, automatic text processing, speech recognition, intelligent sensors and related technologies to infer what they are learning about, who they are learning with, what they want to achieve, and what overarching project and other episodes the learning relates to (Chen & Kotz 2000 see for example ; Lamming & Flynn 1994; Rhodes 1997; Salton 1988). Of course the user can at any point override or delete the automatically created links, or can add new links, at will.

The ideal LLO incorporates a project organisation review interface, which enables the user to have an overview of their learning projects over any given period of time, by providing at a glance details about the number of projects, the topics they relate to, and related past and planned learning episodes. The user can either have a full view of all the projects in a given period, or apply suitable filters. The user can choose to review specific learning episodes: the episode's contextual information (people involved, location, etc.), the activities that they performed and the objects they used. Filtering of episodes is also possible, for example by specifying certain episode context parameters (e.g. display episodes that involve a specific person).

Text searches are possible, both on notes documents and on the space of projects, episodes and activities, allowing the user to arrive at specific pieces of information directly, without any need for navigating within their personal learning history. Note, however, that for text searches to work the user needs to remember what they know – whereas

the advantage of associative retrieval through such navigation is that the user has the ability to recall knowledge and resources that they no longer remember they possess.

Discussion

The concept of LLOs as sketched by the identified requirements has many parallels and connections with Learning Organisation Information Systems (LOIS), with Personal Information Management systems (PIMs), and with e-Portfolios. LOIS (Williamson & Iliopoulos 2001) target the learning of organisations and require the ubiquitous capture and documentation of learning through normal work and learning practices; and also require easy, just-in-time retrieval of that learning. PIMs are event-based personal information retrieval systems (Bovey 1996; Chalmers *et al.* 1998; Eldridge *et al.* 1992; Freeman & Gelernter 1996; Lamming & Flynn 1994; Lamming & Newman 1991; Lansdale & Edmonds 1992; Plaisant *et al.* 1998; Yiu *et al.* 1997) that utilise episodic context for the retrieval of personal information resources and content. e-Portfolios enable the management of digitised collections of learner-created artefacts and their sharing with others (Lorenzo & Ittelson 2005). We should emphasise the need for synergy between these types of tools, to enable not only the private organisation of personal learning and knowledge, but also its (formal or informal) sharing within a learning community.

Concepts similar to those described above as part of LLOs are being incorporated in a file system and interface for the One Laptop per Child (OLPC) project (<http://www.laptop.org>), whose mission is to develop a low-cost laptop (the \$100 laptop) for children in developing nations (OLPC 2007). The OLPC interface is based on the concept of 'activities' that pupils can perform and record in a 'journal'. Starting in a 'home' page, where active and recently publicised activities are listed, the student can resume an activity, join or offer to share activities, or start a new one. The OLPC interface, like the LLO, intends to replace the desktop metaphor with an activity-based interface that takes the focus away from 'things' saved in files and folder hierarchies, to 'things' done in the course of learning.

The LLO concept brings up a number of issues in need of further investigation. An important issue for all life-logging applications is whether the revisiting and revision of a captured episode constitutes a new episode in itself. In the context of an LLO the question translates to whether the learning log should be extended to include a new entry about the revision of a past entry. Or whether the revising should result in the modification of a past entry, in which case versioning of learning log entries may be appropriate. Another related issue is whether the user should be allowed to delete past log entries. Beyond the technical aspects of these issues, the underlying question is how do learners want to recall their past? Are they likely to want to forget learning episodes at will, or to alter their memories? Research suggests that experience can transform memories (Greenhoot 2000); whether the moment of memory transformation constitutes a memorable learning event in its own right needs further clarification.

Although LLOs are envisioned to support the creation of external representations of semantic context and their interrelating with episodic context, it is not clear how the process of restructuring our semantic associations to fit newly learned concepts within a specific episodic context actually takes place: how does the process of abstraction work and how can LLOs best assist it are questions for future research.

The recording and storing of personal information by LLOs bring forth issues of privacy: do learners want to share their records of learning experience? With whom – teachers, peers, colleagues? Who owns the shared records of experience – the teacher? The student? The employer? In KLeOS all the captured data is for personal use only and is not meant to be any more shareable than the user's non-captured learning memories. However, issues of privacy, ownership and security of data need to be resolved when designing systems that aim to store personal information over a lifetime, giving the user/learner control over how the information is gathered, who it is presented to and in what form (see for example Schreck 2003 for an analysis of privacy and security requirements in user modelling).

Storing information over long periods of time also brings up technical issues related to data compatibility and persistence – for example, changing legacy formats supported by word processors may render old electronic documents unreadable. Although standards such as ASCII have survived since the 1960s, and backward compatibility with such 'core' standards for public data archiving is generally well supported, the preservation and maintenance of data that is usable throughout a lifetime is an important technical concern in the design of LLOs.

People's ability to recall some episodes more easily than others is also a factor that needs to be considered. Some of the life-logging projects mentioned previously in the paper address this through algorithms that calculate the memorability of a certain event in terms of its distinctiveness: episodes that are not repetitive, or that take place in unusual social, physical, or technical context, are more likely to stand out in a person's memory compared with more routine episodes (see for example Horvitz *et al.* 2004). This may affect the extent to which episodic memory will be useful in recall. To an extent, the LLO's ability to combine episodic and semantic memories may be the answer to such limitations of episodic memory; however, thorough evaluations of LLOs are necessary to assess this effect.

Evaluation of LLOs is itself a challenging area. LLOs are designed to be used as part of the learner's everyday learning practice, and they offer facilities to access materials and to make notes for topics that are of genuine interest to the learner as well as to retrieve past knowledge and materials for personal use over a lifetime. In contrast, the evaluation presented in this paper was based on an artificial, externally imposed, time-bound learning task that was not necessarily meaningful for the learners, and the knowledge retrieval context was not necessarily relevant to the learners. Moreover, a 60-minute learning episode like the one that was the context for the evaluation is not an ideal way to capture the way episodic memory works: the experiment involved a singular learning task which is likely to stand out in participants' memory, with an internal structure that does not encourage multiple representations in episodic memory. A final shortcoming has been the small number of participants and their background and enthusiasm for both IT and educational technology. Although a knowledgeable group like this can be an advantage in formative usability evaluations like those reported in this paper, at the same time it makes generalisations to other groups or types of learners difficult. We will thus reiterate Lansdale and Edmonds' (1992) argument that longitudinal, *in-situ* studies are necessary for the evaluation of this genre of tools.

Conclusions

In the above we have presented the concept of Lifelong Learning Organisers (LLOs). We have documented the need for LLOs through an empirical study of the everyday learning practice, and have drawn an initial list of general requirements for LLOs based on the empirical study, the design of the KLeOS prototype, and its evaluation. Based on the requirements, an ideal LLO would be a system that quietly sits in the learning background, capturing learning activities, episodes and projects as well as the learner's personal notes, extrapolates relations between the captured items, and allows the learner to retrieve the captured content as necessary in the future, through retrieval mechanisms that are based on episodic memory, semantic memory, and free-text searches.

We propose LLO-type tools for an emerging learning society the citizens of which need to be continuously (re)learning in order to fully exploit the learning opportunities on offer for their personal development, fulfillment and enjoyment. We view the deployment of such tools not as the end point, but rather the starting point for more, and exciting research: tools are designed to aid practice, but tools also change and affect practice. Often the way people adopt a piece of technology is not the same way that the designers expected. New tools that enable self-directed learners to organise their learning experiences, resources and knowledge in new ways may transform the way they perceive and practise learning.

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Middle years students' use of self-regulating strategies in an online journaling environment

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ABSTRACT

This study investigated boys' capacity for self regulation in a Year 8 classroom at a regional secondary college in the state of Victoria, Australia. This was an exploratory descriptive study that sought to examine how the use of an online journal influenced students' capacity to adaptively react (Zimmerman, 2002) to self-determined knowledge about the effectiveness of their method of learning and set learning goals (Ames & Ames, 1989; Midgley, Kaplan, & Middleton, 2001). An online recording and online journaling space were developed by the researcher. The journal has been designed to be engaging for young adolescent male students as well as allowing students to set goals and reflect on how they can achieve those goals in an imaginative, non-threatening, and jargon-free environment. The study reported here aims to determine if through the use of this online journal students' capacity to extend their understanding of themselves as learners through the setting, monitoring and evaluating of personal learning goals can increase. These findings contribute to discussion about the important contemporary issue of students self regulation.

Keywords

Self regulation, Middle years, Student engagement, Online journaling

Introduction

Self regulation increases student motivation and engagement by enabling students to customize and take control of their own learning through conscious knowledge of effective strategies and choices (Zimmerman, 2002; Zimmerman, Bandura, & Martinez-Pons, 1992). It gives them opportunities to pursue preferences as well as strengths using an appropriate repertoire of tactics. This study attempts to improve student self regulation through the use of an online journaling website where the setting of goals is an important component. Goals can be seen as important factors in motivation and learning (Schunk, 2003), both of which are key components of self regulation.

There is now an extensive longstanding literature on student self regulation of learning, drawing on research from the 1980s and 1990s (Ames & Archer, 1988; Pintrich & De Groot, 1990; Schunk, 1990; Zimmerman & Pons, 1988). Self regulated learning is broadly defined by Boekaerts and Corno (2005) as the use of strategies to achieve academic growth and well-being goals. Pintrich and de Groot (1990, p. 38) made the compelling point that "student involvement in self regulated learning is closely tied to students' efficacy beliefs about their capability to perform classroom tasks and to their beliefs that these classroom tasks are interesting and worth learning". Pintrich and de Groot (1990) emphasize that students need to have both the 'will' and the 'skill' for learning gains to occur. Schunk (1990, p. 71) puts forward that "self regulated learning occurs when students activate and sustain cognitions and behaviors systematically oriented toward attainment of learning goals".

More recently, Dweck (2000; 2002) asserted that students may enable or constrain their capacity to self regulate learning because of beliefs they hold about their intelligence and the value of effort. She distinguished between students who view their intelligence as pre-determined, and who therefore view effort as superfluous, with students who believed that effort could lead to success. She considered that appropriate guidance and feedback by the teacher to students on the value of effort could have a positive effect on students' capacity to self regulate learning experiences.

An online recording and online journaling space was developed by the researcher (Campbell & Deed, 2007) and utilized in this study. The website is an Assistive eXtra Learning Environment (AXLE), which is a website that was initially designed to be engaging for boys in Grade 6 as well as functional in order to collect data relating to the study (Campbell & Deed, 2007, 2008; Deed & Campbell, 2007). However, in this context it will be used for Year 8 students. Unique aspects of the design included the use of images rather than text; capacity for each student to individualize their journal using images, colors and clothing for the AXLE avatar; a goal-setting and monitoring

cycle; screens to record the boys' affective, behavioral and cognitive engagement with specific tasks; and allowance for the students to upload work samples. Each student's journal was password protected. It was designed to be an interesting space for the young adolescent male students as well as allow the students to set goals and reflect on how they can achieve those goals in an imaginative, non-threatening and jargon-free environment.

Student participants were required to reflect on specific activities conducted in the classroom. Reflection can often be seen by students as an abstract idea that they perceived as irrelevant to their school life. The students were not explicitly told that they were reflecting, rather they were asked to report on their experiences by completing a series of questions. The online journal focused on the students' perceptions of their affective, behavioral, and cognitive engagement of their most recent classroom experience. It also provided an opportunity for the students to set goals and reflect on these goals weekly through the use of a question cycle that went for a period of four weeks prior to being repeated. It is acknowledged that this was a somewhat artificial goal-setting process. Rather than seeking to involve the boys in a process of goal related reflection, the process emphasized regularized thinking about how the boys' classroom behavior could be examined with reference to prior thoughts about possible improvements. In setting weekly questions it was hoped that the boys would start to see links between their goals and classroom behavior. This was thought to be a basis for further in-class work by the teacher.

Self Reflection

Students who use the AXLE online journal are able to self reflect in their own online space in their own time. Zimmerman (2002) states there are two main processes in self reflection. The first one is self evaluation and it "refers to comparisons of self observed performances against some standard, such as ones prior performance" (Zimmerman, 2002, p. 68), someone else's performance or even an absolute standard. The second phase "involves feelings of self satisfaction and positive affect regarding one's performance" (Zimmerman, 2002, p. 68). Zimmerman goes on to state that motivation is enhanced with increased self satisfaction. This study hopes to provide motivation, and in time self regulation to the student participants. In short, in this study, self reflection means thinking about one's own behavior and then being able to modify it accordingly.

Student Engagement

In Australia, there is national and international interest in re-engaging boys in education (Department of Education Science and Training, 2003). Interventions such as new pedagogies, middle years innovations, and curriculum policy redesign (e.g. Victorian Essential Learning Standards) all provide an environment where students are exposed to alternative approaches designed to engage learners.

Lack of engagement is particularly evident with students from lower socio-economic groups. Lokan et al. (2001), for example, argued that recent curriculum reforms have failed to address the obvious disadvantage of these students, and have not resulted in significant gains in engagement, especially in the middle years of schooling. McGaw (2004) claimed that Australia is performing worse than other developed countries in this regard and categorized Australia as high in quality but low in equity. In other words, while the overall student achievement of students is high, wide differences are evident between high and low achieving students. This lack of success seems evident even in schools taking significant action to address the relevance of the content, substance and type of set tasks, the validity of assessment and reporting regimes, and attempts to engage students through adapting inclusive pedagogies and new methods of student grouping.

Various factors may contribute to this lack of participation in schooling and learning. It is possible that these students lack confidence or motivation, are deficient in skills, or give up easily, do not see the relevance of schooling, are unaware of their difficulties, or feel they can succeed at school without effort.

This project is of particular significance as it addresses a need to provide teachers with efficient interventions to enable students to imagine and reconceptualise their learning behaviors. AXLE provides one such intervention as it may allow students to reconceptualise their learning behaviors through the use of not only the journal section, but also through the use of goal setting.

When students log into AXLE they are able to complete a journal. Part of the journal allows students to complete a section that is based on indicators for educational disengagement. These indicators for educational disengagement have been based on the work of Fredricks, Blumenfeld, and Paris (2004) who mapped the multiple definitions of the concept of engagement. The indicators used were: behavioral (following rules, adhering to school 'norms' and involvement in learning); emotional (motivation for learning, sense of belonging) and cognitive (sense of control over learning; use of learning strategies; adoption of a strategic approach to learning).

Student Goal Setting

One of the main foci of this research is the use of the goal setting section on the AXLE website. Schunk (1990) suggests that a goal is something that an individual is actually and consciously attempting to accomplish, while goal setting is where a goal is created and then modified if necessary. Students using the AXLE website will be setting a goal and attempting to accomplish it for it to be thought of as achieved. Goal setting is crucial to success and as schools spend very little time teaching students to focus it really should be introduced (Rader, 2005). Goal setting processes are integral to having effective student learning (Gillespie, 2002), perhaps through the increased persistence of a person who has set a goal (Locke & Latham, 2002). It has been suggested by Ames (1992) that students should be oriented towards mastery goals where the focus is on effort, not ability. Once children are able to have positive thoughts about themselves and their abilities they can be taught how to set both realistic and achievable goals (Szente, 2007). It is also important for students' goals to be realistic and attainable, though, they also need to be challenging (Schunk, 1990). Students perhaps do not necessarily see the relevance of their subjects and setting their own goals makes school appear more relevant.

A study by Page-Voth and Graham (1999) suggests that goal setting has been successful when used in regards to the writing process for middle years students. Their study suggests that improved writing performance can be linked to goal setting. Schunk (2003), suggests that students make a commitment to obtain a goal and then they are likely to compare their performance against the goals. This means that students need to remember their goal while performing the task. However, if a student develops a goal that takes a while to achieve they may lose track of that goal. The AXLE website assists in students being reinforced throughout the life of the goal so that they may be more likely to achieve it. Schunk (2003) elaborates that teachers may need to develop students' goal setting skills by using direct instruction.

Methodology

A case study approach was used for this research, focusing on one school site. The data collected has the advantage of being strong in reality, and allowing attention to focus on the contextually unique features (Cohen, Manion, & Morrison, 2000). Twenty Year 8 boys from this one regional high school participated in this study. The data collection period for this study was in the final school term in 2008. Due to time constraints it was not possible to interview all of the students, so eleven students were interviewed twice, once at the beginning of the study and once at the end of the ten week data collection period. The interviews were electronically recorded and transcribed. The data was then coded and analyzed for emerging themes. The limitations of this method were that explanations and possibilities can only be considered from the perspective of the classroom from the targeted students. The students were also given a student questionnaire to complete; however, due to timetabling issues only eight of the students completed it.

The school involved in the study uses a teacher advisory system, where the students meet with the teachers (and parents) twice a term. During each teacher advisory session the students can set up to three goals with the assistance of the teacher. The goals are then discussed again at the next meeting to see if they were achieved. As part of the online recording space there is a separate goal section, which allows the students to record one of these goals. The students then have the opportunity to go through a question cycle relating to their goal each week, thus allowing the students to reflect on their goal. Self regulation of the students learning is promoted through the use of this system.

This research hinges around the fact that the students will log into an online journaling website. This website was developed using an avatar, which became known as AXLE. The website was designed to be interactive and engaging for the students with AXLE 'talking' and introducing the website navigation to the students when they initially

logged on. AXLE 'explains' to the students they can change his clothes by clicking on some arrows and they can choose a different background at any time they wish. Each time the students log in they can change AXLE's clothes, hairstyle and what he is holding, which includes a skateboard, guitar, basketball and football. This is designed to be fun and engaging for the students. On the left hand side of the AXLE screen the students have several choices they can make. These include creating a journal, looking at previous entries, entering the goal setting section, or the fun stuff (only available after Week 4), dressing AXLE or changing the background screen. This AXLE screen is shown in detail in Figure 1.

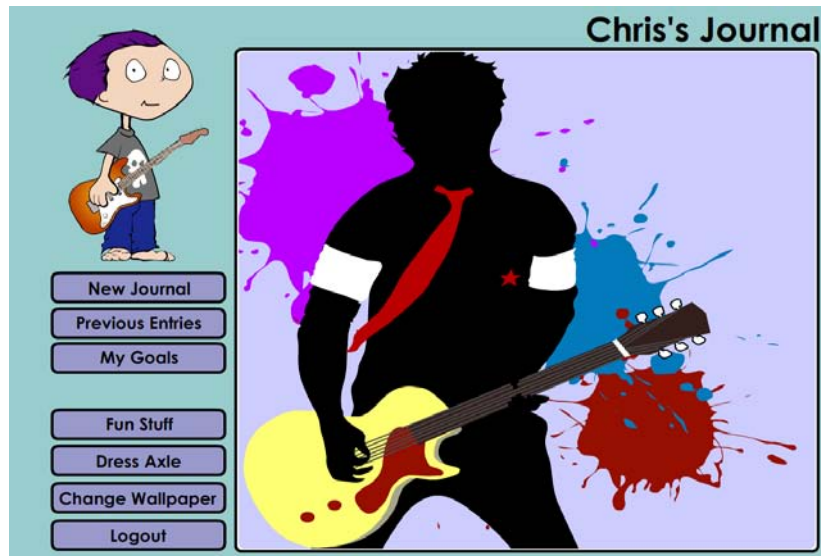


Figure 1. Students can set their own background and dress AXLE in the online journal

When the students click on the 'New Journal' button they can check one to five on a series of statements pertaining to their behavioral and cognitive engagement. There is also a screen to measure student's affective engagement where the students can check a face to describe how they are feeling. When the face is checked it is highlighted by a circle around the image. As many faces can be checked as the student wishes.

As described by Campbell and Deed (2007, 2008), the students were also able to change the background image. These backgrounds included a plain white area, football field, guitar guy, space, circus tent, a dragon, and basketball hoops. These backgrounds were designed after discussion with the boys regarding their local interests. They were meant to be engaging for boys, while the white background was for any students not wanting a 'busy' area.

The AXLE online journaling website requires password access by the students and researchers to enter. Another further restricted website allowed the researchers to access each student's journal entry and to view the work sample they can upload if they choose. This can be in the form of an online text reflection, a .jpg file or .wav audio file. Interestingly, the audio file option has never used by students. This is perhaps because the boys are not given access to the extra equipment needed to make the file. All uploaded files, along with the coded journal entries were then saved on a server for access by the researchers. This allows easy access by the researchers to the student data so that the students can then be interviewed with regard to their work sample and journal reflection. Students are informed the researchers have access to their journals when first introduced to the AXLE website.

As part of the online recording space there was a separate section where the students involved in the study could record a goal. This was a further development from research in previous years (See Campbell & Deed, 2007, 2008; Deed & Campbell, 2007) as it was determined that a goal setting section for AXLE would further develop students ability for self reflection, as is reflected in the available literature (Gillespie, 2002; Page-Voth & Graham, 1999; Schunk, 2003). The students set three goals as part of their meeting with their teacher advisor. They were then given the opportunity of recording one of their goals within the AXLE environment. The goal setting section goes through a series of question relating to their goal, with one question being asked each week, thus allowing the students to reflect on their goal. This is shown in Table 1, and as can be seen the questions are general in their nature so as to

allow the students to reflect on their individual goal, i.e. the questions are relevant to all students, regardless of their goal. If students log into AXLE a second time they are given a different question which also helps them to reflect on their goal. The students are also given the second question for subsequent visits for the remainder of the week, although students generally only log in once or twice. After a goal is entered into AXLE a first time, the goal is displayed on the screen in the goal setting section of AXLE for the students to see (and remember) each time they complete the question cycle. In this study, each question cycle was for four weeks with the cycle being repeated once during the school term.

Table 1. The goal setting section of AXLE has a question cycle

| Condition | Week 1 | Weeks 2/3 | Week 4 |
|--|--|--|--|
| Time | What will help you to achieve this learning goal? | How are you trying to achieve your learning goal? | How do you know if you have achieved your learning goal? |
| Frequency 2 or more visits per week | Why is it important to achieve this learning goal? | How will you know when you have achieved your learning goal? | What other learning goal could you set? |

The students were informed by the teacher advisor that the learning goal had to be expressed as a learning behaviour. Students were experienced in setting goals through the teacher advisor program at the school and so were fairly advanced in their goal setting ability. This meant they were generally able to set relevant and achievable goals.

Results

There are three main themes which have been expanded on below. These were identified through the use of coding of the interviews. The themes are:

- AXLE was valued by the students for reflecting, and frequency of use for setting goals.
- AXLE was valued by the students for assisting with personal control and with future goal setting.
- Students felt that by using AXLE they were able to express private feelings safely.

Reflecting and frequency of use for goal setting

One of the themes that emerged from the results is the value of AXLE as a tool by the students for being a reflection tool, as well as a space for recording set goals. The students were able to use AXLE to set goals with one goal being set and then worked towards for four weeks. To assist in the students achieving this goal they were able to go to the goal space and answer a question each week pertaining to the goal setting question cycle (detailed above).

One student particularly appreciated AXLE's facility for setting and closely monitoring goals. He liked that when he set goals he can look back over them to make sure he is completing the goal. Another student used AXLE primarily as a tool for thinking back over his day at school.

Another student felt that AXLE helped him to achieve his goal of 'asking more questions'. This student stated AXLE "reminded me so then I just started to ask some questions for some things I didn't get". He had set this goal prior to having access to the AXLE program and was unable to achieve it. Through using AXLE he not only achieved the goal, but went on to set another goal which was "to get more involved in discussions". This student set the goal without any prompting from his teachers and was busy working towards achieving the goal. This suggests a great deal of self motivation and advanced goal setting skills.

When one student was asked if AXLE had helped him with his goal setting he replied:

I thought it has cos [sic] it asked me a few questions to get me going and like really think about it instead of just yeah I'll do this soon and keep on putting it off.

This also suggests that AXLE has helped this student monitor and achieve his goals.

One student set a goal to improve his reading. In an interview at the end of the school term, this student told the interviewer that he did a bit of reading on the holidays when he had more free time and made this comment about his reading inside of school:

Student: You can do a little bit of reading in English when you have some time to do it.

Interviewer: and have you noticed any changes in your ability to read or understand?

Student: Yeah as you read you sound more, even the punctuation and everything, you get examples of that throughout the book.

Interviewer: Excellent, sounds like you're becoming more confident and comfortable with words on pages.

Student: Yeah

Interviewer: Does AXLE help, or not help?

Student: Yeah it helps cos each week you come back and have a look over your goal and it reminds you to keep up with my [sic] reading.

This suggests this student is reading more and thus improving his reading. It also suggests that the AXLE website is assisting him to achieve his goal of improving his reading, though doing more of it. Students were able to focus on their goal of how to achieve it through the use of the question cycle provided in AXLE.

One student felt that AXLE assisted him to achieve his goal. He stated:

Well I know in class and stuff you tend to lose focus with all the people talking. I find it hard to concentrate but with the goal setting, and stuff, you really sort of try and think of like you have your goal and you have like little branches coming off with little goals to help.

Although only eight students completed the questionnaire at the end of the school term, these students were positive in the way AXLE assists them with achieving their goals. The students were asked if they thought revisiting their goal in AXLE was important. Seven of the eight students thought that it was with the student who said that it wasn't recording that he could already remember it. From the seven positive responses comments included "so it reminds you of what you need to do to reach your goal" and "because I know I need to complete it", while another student recorded it was important to revisit AXLE "because you could think of ways to reach the goal". These responses are all supporting the interview data that suggests that the AXLE online journaling website assists students to reflect on their goal, be reminded of it and ultimately achieve their goal.

Assistance with personal control and with future goal setting

The second theme to emerge from the results is that AXLE was valued as being able to assist the students with personal control as well as with goal setting in the future. This is particularly suggested by one student who reflected to the interviewers that AXLE puts things into perspective which allows him some personal control over his class situation. He commented:

I think it kinda [sic] puts some stuff into perspective, like whether today I've wasted too much time and not listened to the teachers rather than like arr [sic] and then some days you look at it and oh look I've done this and done this.

This student went on to say that when he doesn't use AXLE he doesn't think about his school work, but contrastingly when using AXLE he thinks about it for the rest of the day which impacts on how he works at school. Another student also suggested similarly when he stated "I think that that helps cos [sic] if you're thinking about that and you might think about it later in the day and then you might put in a bigger effort".

One student reported that someone was annoying him in class and he used AXLE as a vehicle for letting his feelings out. He commented "instead of just yelling at everyone and being mean [sic] I could just say that I was angry", meaning he could write this down in the AXLE journal section.

Express private feelings safely

A third and important theme is that students felt that AXLE allowed them to express their private feelings safely. This was suggested by one student who commented that he did not have enough sleep one day and it was a day he was missing his brother. He said that by using AXLE it helped him to reflect on his day and his week as well as record his feelings in private. He felt that it helped to get it out without anyone else knowing about it.

Although access to AXLE was through a password protected website the students were given an individual password and one student felt that as other students knew this code then perhaps they should be able to go in and change the password if they wish. The student said that although he felt AXLE was secure and students did not go into each other's accounts he thought it would be better to be able to personalize the password.

Overall, AXLE did provide a vehicle for the Year 8 boys to express their feelings in a private setting.

In the questionnaire that was completed by eight students they were asked if AXLE did help with their learning. All students responded positively to this question. Student's comments included "yes, because it helps us focus on how we were at school" and "yes, it really helped with reminding me of my goal". Another student recorded the comment "yes I found it quite helpful. It let me express myself" and yet another student recorded "yes, it helped me reach my goals adding to my learning". These are very positive responses by the Year 8 boys and suggest they have thought about how AXLE is assisting them in school, with their goal setting and ultimately their learning.

Limitations

The main limitation of this study is that the data collected was only from the students' perspective. Although an effort was made to interview two teachers, the interviews were not a success as the teachers did not feel they could comment on AXLE or if the students had achieved their goals. This is despite the teachers seeing the AXLE website several times, including when it was introduced to the students and even from a distance when the students were logged in each week.

Future Directions

Although the implementation of AXLE was not without its challenges this year, it will be beneficial for this research to continue over time, which more in-depth data gathered from a variety of cohorts. It would be interesting to investigate if the boys' skills of understanding their goal setting abilities are transferable to other goals. Perhaps, over a period of time with consistent use of the AXLE program they will be able to identify the key things they need to do to be more informed and productive as a learner.

Another use of AXLE in the future may be to focus on a small number of students who are disengaged in the classroom. By using AXLE they may develop not only some self regulatory skills, but be engaged and motivated enough to use these skills in the while at school. It is expected that this will occur at a different school in 2009.

Students particularly valued their privacy in using AXLE. Perhaps for some, this means that home access should be promoted so that the boys may use AXLE in a secure place. Another way of promoting their privacy may be to allow AXLE to be used by the boys in a private place in the school. This may mean a computer is placed in a secure location and the students allowed out of class to go on the AXLE website at certain times of the day.

Conclusions

From the preliminary results described above, AXLE is able to provide students with improved goal setting ability and the motivation to achieve their goals. This appears to have lead to some self regulation in this regard. By using AXLE it has provided the students with opportunities to express private feelings. This is perhaps an important step forward with the emotional health of the boys and an unintended outcome of the study.

Although in this study AXLE was given minimal importance by the class teachers and not promoted in any way, a previous study found AXLE provided an important learning space within the classroom (Campbell & Deed, 2008). It is hoped that when schools implement a program such as AXLE that it will be given the time that is needed to ensure its use succeeds. It should be noted that even with some adversity in using AXLE in the school, it was certainly deemed successful by the students who were given weekly or fortnightly access to it. It should be noted that despite some challenges to its implementation at the school, AXLE was certainly deemed successful by the students who were given weekly or fortnightly access to it. By all accounts these students are setting goals and working towards achieving them and self regulating more at school.

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Introducing Live ePortfolios to Support Self Organised Learning

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ABSTRACT

This paper presents a platform on which a new generation of applications targeted to aid the self-organised learner can be presented. The new application is enabled by innovations in trust-based security of data built upon emerging infrastructures to aid federated data access in the UK education sector. Within the proposed architecture, users and data providers (within Virtual Organisations formed for specific learning needs) collaborate in a more dynamic and flexible manner by defining their own data-object-based security policies. This is enabled using a Service Orientated Architecture (SOA) that presents trusted services to ensure that these policies are both applied and enforced. The work is significant because it presents a new level of both distributed and live data integration into the ePortfolio domain. New data objects can be integrated into the learning process from emerging areas like social networking, giving the learning processes more depth. For the learner this approach enhances the quality and range of data that they can use in the ePortfolio, and has the potential to enhance the self-organised learning process, which for society in general will enhance learning processes.

Keywords

ePortfolio, Service Orientated Architecture, trust, virtual organisation security, federated data access

Introduction

Data capture, and its effective use and management in relation to user attainment in terms of learning inside and outside of the workplace, is a vital process for aiding personal development in both learning and working environments. Using ePortfolios as a central point of focus for this data has proved to help individuals in terms both of reflective learning and also future planning. Sharing attainment data also assists the user in the process of seeking to secure better-quality employment and more suitable learning. However to date, despite various efforts, ePortfolio solutions that link to live data from organisations and users in a flexible and dynamic manner have yet to be realised effectively.

Dynamically sharing live data from various sources is restricted by the issues associated with information security and sharing. Although the data is often specific to the user, the policies related to sharing this data and granting access to the repositories that store it are fixed at organisational level. The security policies associated with access to the data are not sufficiently fine-grained to be applied dynamically on a user basis, nor specific to data content in a live situation. As a result, the development of ePortfolios to date often requires manual input of data from one system to another as the learner makes a transition, or else provision of separate portfolios in each institution, which often results in data loss, lack of adoption and third-party access – a complex and non-standard process.

Addressing these data integration challenges is the main aim of the TAS³ (Trusted Architecture for Securely Shared Services) project (TAS³ 2009). The University of Nottingham is a partner in this project and has the brief to provide an ePortfolio-based demonstrator to support UK employability. The research detailed in this paper is focused on the work the University has been doing around the integration and development of ePortfolios to support live data integration using the TAS³ infrastructure.

Service Orientated Architectures

Service Orientated Architectures (SOA) are largely implemented using Web Services and are proven to increase the accessibility to shared software and data, as opposed to vendor-specific, often client and server solutions (Papazoglou et al 2003, Foster et al 1999). This is because loosely-coupled service-based architectures present the user with standardised interfaces to otherwise differing and often complex computing environments. Services also

present increased flexibility in applications so that they can adapt better to user requirements and often require fewer resources to support in terms of both hardware and cost (Woods et al 2006). The business computing application of SOA in supply chain management (Lee et al 2000) to eHealth (Omar et al 2006) illustrates how various computing communities are embracing SOA. The increased flexibility using SOA in these communities has decreased the cost for business users by changing business models, and specifically allowing application providers to compete alongside each other around specific elements of wider SOA.

Flexibility in loosely-coupled SOA is driven by the need to support real-time, dynamically-selected services and data. For example, web services on devices are present in a new generation of pervasive computing applications: the use of GPS devices in transportation or personal communication devices can both link the user to information that is influenced by location (Aktas et al. 2005). The use of Web Service standards makes access to this information standards-based using the internet as the communication medium. By increasing application pervasiveness on the one hand and application flexibility and dynamicity on the other, SOA presents users with a new generation of personalised specific real-time services.

As real time information is incorporated into distributed applications the relationships of data and services become complex and have to be managed. The majority of this management has to be done automatically to support the needs of both the user and service providers in the architecture. These needs are specified when the parties join the SOA-driven application which is referenced by the services when using real-time data sources (Nguyen et al 2005). In terms of the learning process, the ability for the application to change in real time has a great advantage over existing eLearning applications. For example, the learning environment can change to suit a variety of environmental factors, which could include changes in the workplace, the economy, user requirements or even personal changes of interest generated by the user's updating of social networking data..

Thus, distributed services can form composite applications that combine data from various sources that can present users with a new dimension in terms of learning resource. However this greater ability to combine and deliver data needs to be matched with technical advances in terms of data management and security; within the computing community these advances are emerging from the security policy domain. The definition of policies associated with data objects varies between users and domains: for example, in the learning domain of ePortfolio, policies associated with the data objects for learning may not be as restrictive as those associated with records in the medical domain. Therefore policy definition and enforcement will vary in these emerging distributed architectures on organisational, personal and application-specific lines, thereby presenting integration difficulties.

The challenge of cross-domain policy integration in dynamic distributed architectures has to be automated in order to maintain application flexibility. This automation of integration is achieved via policy negotiation mechanisms; these involve the negotiation of security policy to establish levels of trust effectively between large numbers of users and organisations. Trust negotiation between parties has been the subject of previous SOA-based projects in various domains (Yang et al 2006, Jesang et al 2007) and is an essential area of research vital for the development of cross-domain SOA. For ePortfolio development this research is equally essential as without cross-domain co-operation and trust the potential of live, real-time ePortfolios will not be realised.

Trusted Federation

The 'Internet2 Middleware Initiative' has played an active role in the development of an '*an interoperable Identity and Access Management infrastructure for Research and Education*' which forms the foundation of federated access. One such framework implemented in the UK is the 'UK Access Management Federation for education and research, developed jointly by the JISC, JANET(UK) and SDSS of the University of Edinburgh to support the UK education system. The federation exists as an advanced example of a Trust Fabric using the SAML 2.0 based Shibboleth software.

A number of National Research and Education Networks (NRENs), both in Europe and the rest of the world, have adopted technology which allows learners to gain access to facilities when away from their home institution. Two of these technologies are Eduroam, the European roaming service which gives wireless access to individuals from institutions who have signed up, and 'Shibboleth', which provides the basis of 'The UK Access Management Federation for Education and Research' and many other European federations. These federations have adopted 'trust fabric' which is central in open learning systems such as the development of the live ePortfolio. In such systems the fundamental principle of the Identity Provider is used to provide the authentication for users who need access to a

service. At one time, if users required access to a service the provider would need to have their specific details: this is not the case with the trust fabric.

Instead, once the users are granted access via a federated access management login, they are able to gain automatic access to other services available to them as members of the same federation without having to sign on again. This principle can easily be applied to the ePortfolio concept in one of two ways. The service providers and institutions can either join an existing federation such as ‘The UK Access Management Federation for Education and Research’, or the project leaders can set up an isolated federation or outsource to a third-party organisation. Whatever the choice, the use of standardised protocols, for example SAML 2.0, is recommended. The exchange of attributes between federations would have greater transparency using similar standards. SAML 2.0 is considered as the emerging standard for such attribute exchanges. One of the objectives of federated access is to allow Single Sign On and this is being explored as part of the TAS³ framework in the ePortfolio trials.

ePortfolios and learning

Within the UK the development of personal records of achievement for school learners began to be adopted in the 1990s (Assister et al 1993). This area of support has evolved a major focus on ways in which holistic views of the learner from school to workplace can be achieved. This can be seen as linked to the growth of the concepts surrounding the knowledge society, in particular around the greater focus on the role of the individual within and outside of organisations (Delanty 2001), particularly when these seek to continue developing individuals throughout the full span of their working lives. Lifelong Learning, collaborative environments, communities of practice and ePortfolios are all important concepts in the role of personal development: hence a new emphasis on pedagogy and design of learning systems, in particular e-learning environments, as a structure for learning outside of the institution and within the workplace. Learning theories such as Constructivism are used to complement these structures as researchers seek to study the associated pedagogy.

Significantly the emergence of ePortfolios as a central tool to support autonomous and dynamic learning and knowledge exchange between institutions and organisations is increasingly being recognised. The use of ePortfolios allows both the individual and the organisation to make informed choices regarding users’ development. In terms of learning process, the use of ePortfolios allows individuals to organise, structure and reflect on learning, providing the opportunity for both to adopt a constructivist approach to learning.

The online learning platform currently includes many positive attributes for learner support, providing an ideal framework to promote higher order thinking for students. In terms of learning movements, this concept fits well under the Active Learning umbrella. The basic principles of Active Learning are to allow students to be more interactive and reflective through open lines of communication (Silberman 1996). The challenge the ePortfolio system faces in terms of Active Learning is how it can provide the group dynamics and problem-based learning environments required. Through ePortfolio use students have the opportunity to take responsibility and ownership of learning and to reflect not only on the learning but also the processes; however the onus is often on the student to manage the main content of the folio. Increasing the live nature of the data in the ePortfolio can enhance the ability of the student to function around real-world problems, aiding learning and the ability to authenticate strategies towards real world skills through co-operative collaboration between tutors, peers and mentors (Bostock 1997).

ePortfolio Development

Typical ePortfolio

As already discussed, ePortfolio development can be seen to originate from learning practices such as records of achievement. The ePortfolio can be seen as a more student-focused means of maintaining records of learning and development. Technically, the most typical ePortfolio implementation can be seen as a portal-based website in which the learner and teacher can access different elements. The main actors and their relationship with the ePortfolio can be seen in Figure 1.

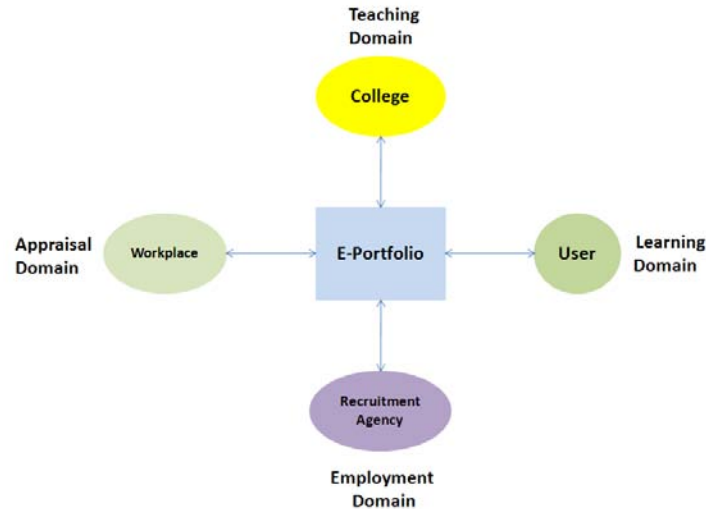


Figure 1. Typical ePortfolio deployment

Figure 1 illustrates how the ePortfolio is a central point of collaboration between the four main parties illustrated. Within these, only the recruitment agency uses information from the ePortfolio without adding any data back. As an agency to recruit either for college or a workplace, the relationship with the user is a one-way process. However before the actual use phase, it could be possible for an agency to collaborate with the other parties in the design/purpose of the ePortfolio, for example to aid recruitment for specific job categories.

Within the UK the Government agency Becta (formerly known as the British Educational Communications and Technology Agency) funded a study into the main purposes of ePortfolio development. Becta summarised these as:

Showcase or Presentation Portfolio: Enables the student/author to share examples of their work which may be in specific collections for differing purposes.

Qualification or evidence Portfolio: Evidence gathering for formal qualification validation. Requires external authentication of held records and provides the e-assessment interface. This may also contain the student's qualification history.

Learning or Development Portfolio: Personal Development Planning (PDP) provides the student's learning plan with identified goals and learning outcomes. Interface may allow support and feedback from peers, mentors, coaches and tutors.

Lifelong learning Summary Portfolio: This is the student's continuing professional development area. It provides summary information on a timeline. This may include a CV generator.

Transaction Portfolio: This area is for the student's eyes only. Enables capturing and editing of information before posting into another area. Contains personal diaries, journals and 'Blog' information. Information filing and retrieval utilities.

(Becta 2008)

What is significant about the Becta study is that the model for ePortfolio deployment can be seen as inadequate. This is because it presents a static view on the types of ePortfolio. It is assumed that separate ePortfolio software packages are created for specific tasks. Therefore as discussed, the ePortfolio is specific to the organisation and application. In this respect, the ePortfolio can be seen as no more useful than a CV that is created as a static, time-stamped document in a specific format; in both cases, sharing requires the receiver to open documents manually and interrogate the information inside. It is much more desirable to create the themes as described in the Becta study as views of data from single points of ePortfolio, otherwise the amount of ePortfolio has to be integrated along with the data.

Live ePortfolios

Service-based improvement for ePortfolio use is the integration of the users with the data. This will enable the different types of ePortfolio to be present within a single application and interchange as different data views, as

opposed to requiring separate ePortfolios. This can be seen as a live use of ePortfolio and will create new levels of integration of data approach to how data is handled by the various parties involved. Essentially, the relationship around greater automated use of data by these parties will need a delicate and secure data management framework. As illustrated in figure 2, the ePortfolio is owned by the various organisations, all of which have maintenance roles within it. The ePortfolio no longer becomes a separate object as it is in Figure 1, but rather it can be now seen as a area of focus for collaboration between parties.

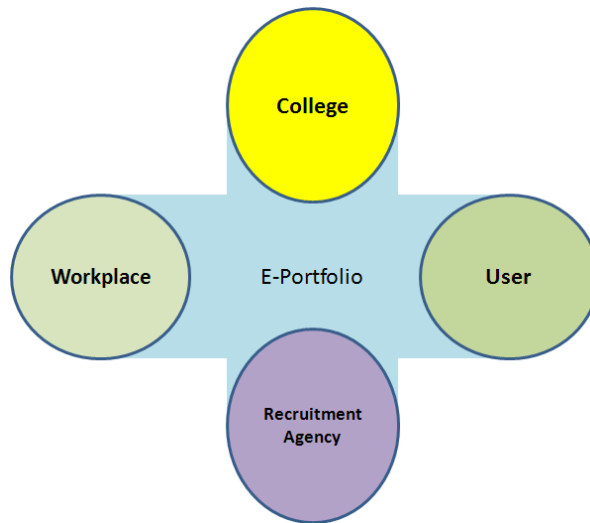


Figure 2. Live ePortfolio owned by its maintainers

Within Figure 2 the ePortfolio forms a domain of collaboration, within which all the parties are present. This concept of a collaboration domain can be seen in previous distributed computing research, particularly in the field of Virtual Organisations (VOs); the creation of a collaboration domain using the concepts of VOs will provide the actors in VO with a secure and reliable system to support the automated sharing of specific data from each partner (Foster et al 2001). Within this domain, services will provide both application-specific support, such as data sharing between the user and workplace, and also infrastructure services, such as security and monitoring of data use.

For the user, the new model will present greater access to data to aid reflective learning and development. However other third party services can also be developed within the VO framework to enhance this data use within the domain of Active Learning. For example, one such use may be the fusion of the user's social networking data within the VO. This could then be used by college and workplace services to tailor learning and personal development to suit the user's individual social interests.

Implementation

The main use case for the live ePortfolio at the University of Nottingham for the TAS³ project is in the domain of personnel development. In order to merge data from various institutions a trusted federation framework has had to be developed. A trial to pilot a student placement demonstrator is being designed between the Placementmaker scheme run for the University's International office and local Small to Medium Enterprises (SMEs) in the area. This pilot brings together the four main parties of the learner, SME, University and placement provider (replacing recruitment agency in figure2) around an ePortfolio for learner development.

Existing system

The learner development ePortfolio can be seen to contain two main elements, the first being recording of personal learning development and the second relating to more formal records. To date, the linkage between the user and the

placement scheme has been a manual one, based on the automated validation of the user's student ID when they register for the program. Once the student is on the placement an ePortfolio is shared by the three parties involved, but the frequency of updating depends on their motivation. Therefore the standards and use of ePortfolio can differ widely during placements and there is no real way to help either party regulate the development of the ePortfolio. This is despite the fact that it is likely that useful data for the ePortfolio will be stored in separate record systems. Again this separation can be seen as linked to dependency on legacy system and organization specific data security policies.

The trial at Nottingham proposes to illustrate how these barriers can be broken down within the three phases of development of the test bed.

Phase 1 Joining

Phase 1 is concerned with linking the University systems into the ePortfolio. Here we are looking to link associated student data directly into the ePortfolio from the registration process. This will enable the user to be presented with an ePortfolio already containing data about both their placement details and also any assessment requirements the organisation or the University may have. This data can also be linked to the University's learning objects to aid the student in the self learning process..

Initially this linkage will enable the user to use the ePortfolio as a resource to aid integration into the workplace via the use of learning objects provided by both the employer and educational institution. In addition, student data will automatically be available for use within the workplace, which will in turn ease any workplace induction process. Both uses of the ePortfolio will introduce both parties to its potential uses.

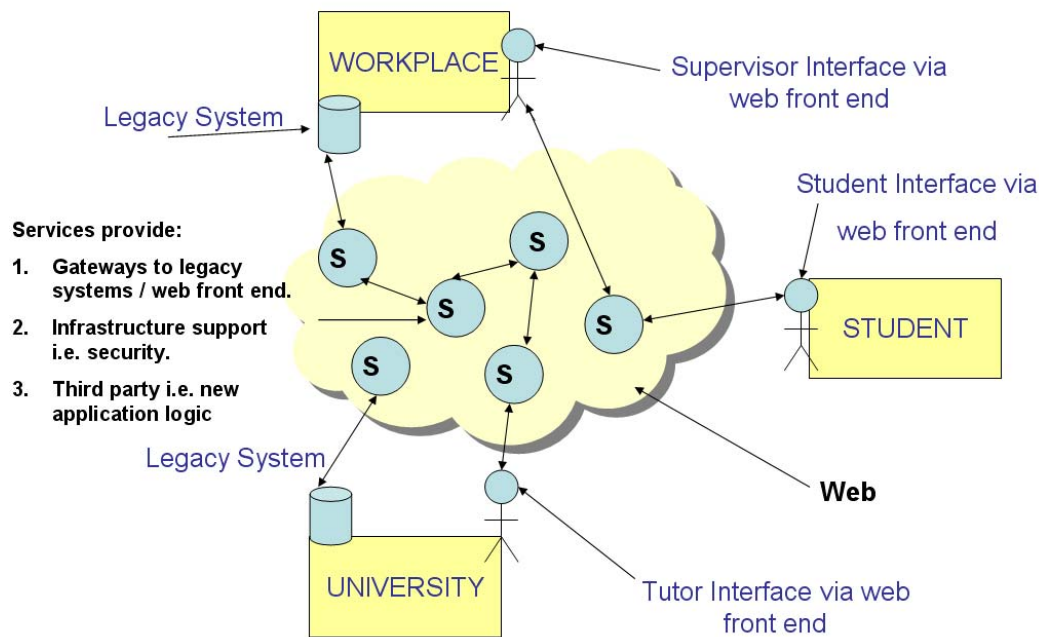


Figure 3. Live ePortfolios and third party services

Phase 2 Population

Phase 2 can be seen as the ePortfolio population phase and aims to enforce Active Learning around the ePortfolio. Here the ePortfolio is linked into the workplace staff appraisal systems. This will allow ePortfolio to keep records of work-based assessment.

Furthermore, from the learning side the ePortfolio is linked to a project plan reflecting both the main aims of the placement and the student's academic development. The work-based assessment will compare against this and other student learning data using services aimed at enhancing the learner's experience. These extra sets of services can be seen as adding value to the learning process and can be introduced by specialist third parties as in Figure 3.

Phase 3 Evaluation

Phase 3 of the implementation aims to place the data gathered in the placement in a more global perspective. Using the same policy frameworks, data from various placements can be compared and evaluated in terms of student attainment and also achievement. Placement providers and students can be grouped and encouraged to join special interest groups around areas of both learning and industrial development.

Future Work

The implementation at the University of Nottingham is handling both technical and cultural challenges in terms of this new level of ePortfolio use and adoption. A key hurdle in terms of use is the interaction between users and the way that the security policies for their data is defined. To date, although standards that can express security policy are available, there are no effective tools to aid users in the creation of policies from a non-technical perspective. Therefore the policies are often set either through default or via rather basic interfaces with the users. A richer method of policy setting is vital to ensure both the flexibility and effectiveness of this new level of collaboration around the ePortfolio.

In terms of the trial, another phase of development will look at tailoring the ePortfolio to recruiters and other educational institutions, as the recruiter or other potential learning/training provider will have different interests in how the data in the ePortfolio is presented. This phase will link the needs of these institutions and will require a more flexible level of data viewing in the ePortfolio. This will give the project the opportunity to develop the template idea for live ePortfolios. As for recruiters, a range of templates will be used either to interrogate the ePortfolio or to match the information within it to the legacy systems of their customers, for example using XSLT, or work around the emerging XCRI standard (XCRI 2009) being developed for describing course-related information in the educational community.

Conclusion

Live ePortfolios will push forward the adoption of service-oriented computing into the world of learning. This process will combine learning data with information previously separated from learning processes due to technical and application restrictions. For example, the combination of social networking data with learning data is a relatively new area of research and implementation. However, the vision of the live ePortfolio is dependent on the development and adoption of a trusted infrastructure that can support both users and service providers. To date this is being achieved in the academic community in projects such as Internet 2; however the real enhancements will come through the adoption of greater levels of policy usage and refinement as being tested by TAS³.

The work in this paper sheds more light on how the current innovations in trust within the academic community can be joined with innovations in learning around ePortfolios. These two separate interest areas are linked technically, and have the potential to demonstrate to the wider community how learning, technology and users can be combined in a new generation of learning applications.

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Effects of the ISIS Recommender System for navigation support in self-organised Learning Networks

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ABSTRACT

The need to support users of the Internet with the selection of information is becoming more important. Learners in complex, self-organising Learning Networks have similar problems and need guidance to find and select most suitable learning activities, in order to attain their lifelong learning goals in the most efficient way. Several research questions regarding efficiency and effectiveness deal with adequate navigation support through recommender systems. To answer some of these questions an experiment was set up within an Introduction Psychology course of the Open University of the Netherlands. Around 250 students participated in this study and were monitored over an experimental period of four months. All were provided the same course materials, but only half of them were supported with a personalised recommender system. This study examined the effects of the navigation support on the completion of learning activities (effectiveness), needed time to comply them (efficiency), actual use of and satisfaction with the system, and the variety of learning paths. The recommender system positively influenced all measures, by having significant effects on efficiency, satisfaction and variety.

Keywords

Informal learning, learning networks, recommender systems, collaborative filtering, learner profiling

Introduction

Learning Networks (LN) strongly differ from traditional virtual learning environments because they are driven by the contribution of their members (Koper & Tattersall, 2004). Traditional approaches are designed top-down, because their structure, learning resources, and learning plans are predefined by an educational institution or domain professionals (e.g., teachers). In LNs, also the learners are able to publish their own learning activities (learning resources), or share, rate, and adjust learning activities (LA) from other learners. Thus, LNs explicitly address informal learning but are also capable to integrate formal learning offers. As a consequence of this more informal character, LNs have several functionalities in common with Web 2.0 technologies nowadays. One effect of Web 2.0 technologies is the dramatically increasing amount of available information, which also applies to LNs. It is a common problem for users of the Internet to select or discover information they are interested in. The need to support users with the selection of information or giving reference to relevant information in order to improve their self-organisation is becoming more important.

This is where navigation plays a major role. Navigation has been defined as “the process of determining a path to be travelled by any object through any environment” (Darken & Sibert, 1993) to attain a certain goal. Therefore, the object requires a position, feedback about the environment, and an idea about its goal. The learners in dynamic and informal LNs are in need of supportive information in order to self-determine their position, to self-regulate their learning path, and to adjust their competence development to their learning goal. Considering this definition, navigation support in informal LNs has major influences for the self-organisation of the learners. Information about other learners’ behavior is beneficial for the individual learner in the self-determination and self-regulation of the learning process.

We have carried out an experimental study with personalised navigation support within the ISIS project, and this article presents the setup and results from that study. Members in complex, self-organising, informal LNs need guidance in finding and composing their most suitable LA (route guidance), in order to attain their learning goals in the most efficient way (Prins, Nadolski, Drachsler, Berlanga, Hummel, & Koper, in press). The innovation of the research is the implementation of existing recommender system technologies into self-organised, informal LNs to

support lifelong learners. Therefore, our focus is more on the evaluation of the learning outcomes through personal navigation support systems like recommender systems and less on measures like algorithm performance of the machine-learning field (Sarwar, Karypis, Konstan, & Riedl, 2000; Huang, Zeng, & Chen, 2007) which heavily influence the recommender system research.

The main purpose of recommender systems on the Internet is to filter information a user might be interested in. For instance, the company Amazon.com (Linden, Smith, & York, 2003) is using a recommender system to direct the attention of their users to other products in their collection. Existing 'navigation services' help to design and develop specific solutions for lifelong learners. Personal recommenders systems (Adomavicius, Sankaranarayanan, Sen, & Tuzhilin, 2005) are becoming increasingly popular for suggesting tailored information to individual users. In this article we discuss the effects of the ISIS experiment with a personal recommender systems (PRS) for LNs. Section two will describe our approach to navigation support in technology-enhanced learning, and presents our hypotheses for the experimental study. In the method section (third section) we describe the experimental design and the used recommendation strategy. In the results section (fourth section) we will describe measured observations and effects in response to the hypotheses. Finally, the fifth section discusses the effects and limitations of the study, and gives an outlook on future research.

Our approach to navigational support in technology-enhanced learning

In technology-enhanced learning navigational support is needed when learners fall short of answers to questions like: How do I find learning activities that best match my situational circumstances, prior knowledge, or preferences? PRS are promising tools for a better alignment of learner needs and available LAs. The motivation for PRS in self-organised LNs is enabling more personalised learning paths, while at the same time taking into account pedagogical issues and available resources. One way to implement pedagogical decisions into a PRS is to use a variety of recommendation techniques in a recommendation strategy (Setten, 2005).

Recommendation strategies are a combination of different recommendation techniques to improve the overall accuracy of any recommender system, and to overcome disadvantages of one singular recommendation technique. Such recommendation strategies are implemented into hybrid recommendation systems, because they combine different recommendation techniques in one recommender system (Hummel, Van den Berg, Berlanga, Drachsler, Janssen, Nadolski, & Koper, 2007). Recommendation strategies can be used in technology-enhanced learning to apply specific recommendation techniques in particular learning situations. The decision to change from one recommendation technique to another can be done according to pedagogical reasons, derived from specific demands of lifelong learning (Drachsler, Hummel & Koper, 2008).

The PRS that we used in ISIS combined a top-down, ontology-based recommendation technique (Middleton, Shadbolt, & De Roure, 2004) with a bottom-up, stereotype filtering technique (Sollenborn & Funk, 2002). Both techniques were combined in a recommendation strategy that decided which of the techniques were most suitable for the current situation a learner was in. If stereotype filtering was used to create a recommendation the next best LA was based on the most popular LA of a specific learner group using Collaborative Filtering. In case the ontology was used to create the recommendation, learner preferences (taken from their user profiles) were matched to the domain ontology to recommend the most suitable next best LA.

The following 4 hypotheses were tested in the ISIS experiment, where the control group was provided with the Moodle learning environment and a text book; whereas the experimental group was additionally provided with a PRS that recommended best next LA based on successful choices of other learners with similar profiles:

1. The experimental group will be able to complete more LAs than the control group (Effectiveness).
2. The experimental group will complete LAs in less time, because alignment of learner and LA characteristics will increase the efficiency of the learning process (Efficiency).
3. The experimental group has a broader variety of learning paths than the control group because the PRS supports more personalised navigation (Variety).
4. The experimental group will be satisfied with the navigational support of the PRS (Satisfaction).

In the next section (method section) we will describe the experimental design and the used recommendation strategy in more detail. In section four results and statistical effects will be presented.

Method

To test our hypotheses in an authentic learning situation, we carried out an experimental study within the regular “Introduction Psychology” course as offered by the Psychology faculty of the Open University of the Netherlands (OUNL). This new course was offered as alternative next to the existing, old version of the course. The LAs and the PRS were implemented in the Moodle LMS (Dougiamas, 2007).

Participants

No prior knowledge was required from the participants to attend the Introduction Psychology course. A total of 244 participants subscribed to this pilot. Both the experimental and control group contained an equal amount of learners (122 learners per group) because the learners were randomly allocated. 24 participants (19.7%) in the experimental group and 30 participants (24.5%) in the control group never logged into the Moodle environment. This group of non-starters was not included in our analyses. This leaves a group of 190 learners who did enter the Moodle environment; 98 in the experimental and 92 in the control group.

From the 98 participants in the experimental group 60% of them were women, within an average age of 38,5 years, and 70% of the participants had a higher professional education or university level. In the control group 65% of them were woman, within an average age of 34,7 years, and 62% of the participants had a higher educational level.

The group of actual starters had to be further differentiated into active and passive learners, because not all of the learners actually used or made progress in the Moodle environment. From the 98 participants in the experimental group 72 learners completed LAs; from the control group 60 learners completed LAs. Thus, in total a group of 132 were active learners during the experiment. We used this total amount of active learners to analyse hypotheses 1 (Effectiveness), hypotheses 2 (Efficiency), and hypotheses 3 (Variety). The group of participants was further characterised by an average age of 36.5 years, 62.5% being female students, and 66% having a higher education level.

Materials

The Learning Network

Moodle was adjusted to the experimental setup. Figure 1 shows the overview screen of LAs for a learner in the experimental group. The overview is divided into three columns. The right column shows the LAs the learner still has to study. The middle column presents the courses the learner is already enrolled for. Finally, in the left column all completed courses are listed. Below an explanation of the recommendation is given. In this screen, the PRS has recommended ‘Thinking’ as next best course. Next to the recommendation there are additional options to get further information about the recommendation and to adjust the preferences set in the learner profile.


| Overview of learning activities | | |
|---|---|---|
| You already completed: You have not completed any learning activity. | Activities you are enrolled into: Perception Personality Awareness Changes during the life time Therapies Language | You still need to complete: Behavior and health Thinking Social Psychology Conditioning and learning Abnormal psychology Recall and neglect Intelligence The biology of behavior Motivation and emotions Attention and awareness Applied Psychology |
|  Based on your study interest in " cognition " (mentioned in your personal profile), we suggest to further study the following learning activity: | | |
| Title of the suggested learning activity | | Options |
| Thinking | | description of the recommendation adjust profile |

Figure 1: Overview page of the experimental group with a recommendation

The LN contained 17 LAs with an average study load of 12 hours. Formal completion of each LA was assessed by multiple-choice tests consisting of seven equally weighted questions. A score of 60% or more was considered as a successful completion of the LA. With the Moodle environment the learners received an Introduction to Psychology handbook that contained additional information to the 17 LAs. All LAs were separate entities in Moodle, setup according to the same didactical structure. The Moodle environment contained all further learning materials, including support and guidance, task assignments, progress tests, additional pictures and links, summarizations, and other attractive learning tasks.

The Personal Recommender System

The PRS with a combined recommendation strategy provide more accurate recommendations when compared to single techniques PRSs (Melville, Mooney, & Nagarajan, 2002; Pazzani, 1999; Soboro & Nicholas, 2000). The implemented PRS combined an ontology-based recommendation technique with a stereotype filtering technique. The ontology used personal information of the learner (e.g., interest) and compared that with the domain knowledge to recommend the most suitable LA. Stereotype filtering used profile attributes of the learners (e.g., interest, motivation, study time) to create learner groups and recommend LAs preferred by similar learners.

The PRS advises the next best LA to follow based on the interest of learners (ontology-based recommendation), and on the behaviour of the peers (stereotype filtering). If only information about the interest of a learner was available, then ontology-based recommendation technique was used, else the stereotype filtering technique was applied. The underlying recommendation strategy is presented in Figure 2.

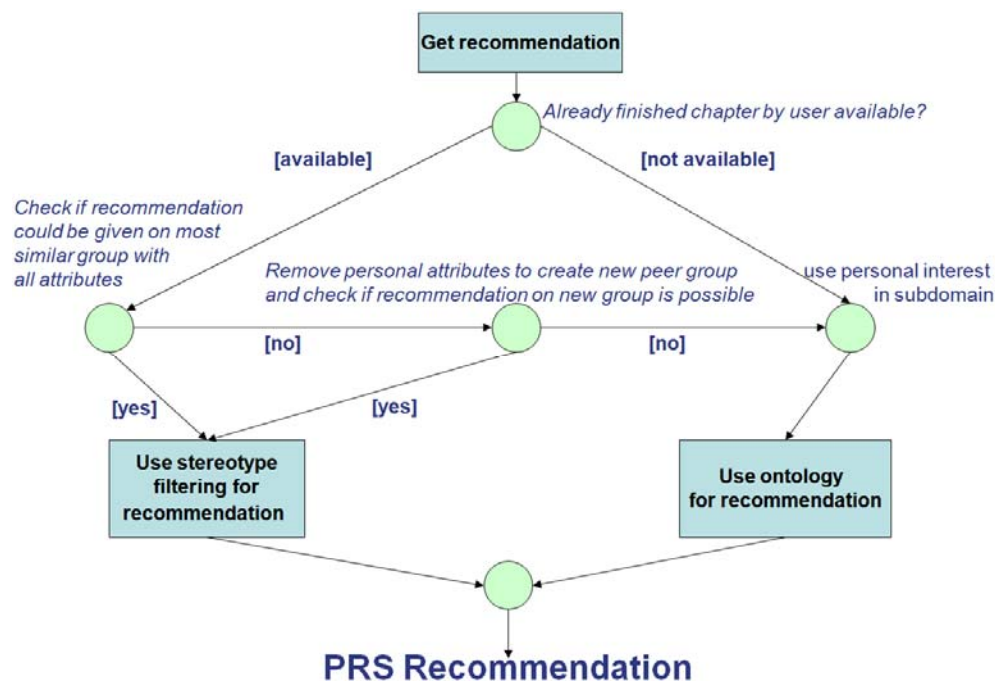


Figure 2: Recommendation strategy for the implemented PRS

The use of the stereotype filtering was prioritized and the ontology approach was used mainly to cover the ‘cold-start problem’ (Herlocker, Konstan, & Riedl, 2000) of the stereotype filtering technique. The stereotype filtering technique was personalised through attributes of the personal profile of the learners. If it was not possible to give any advice it disabled one of the personal attributes and tried to make a recommendation based on larger peer group with less common attributes (Figure 2).

Only in the case that the stereotype filtering was not able to provide any recommendation, the PRS created ontology-based recommendations. The ontology visualized in Figure 3 consists of two top domains (e.g., ‘Environmental

Psychology’) that contain several sub domains (e.g., ‘learning’), each containing two or three courses (or LA) (e.g., ‘recall and neglect’). The learners had to select a special interest (one of the sub domains of the ontology) in their profile. If the learners had chosen a sub domain (e.g., ‘clinical’), they received recommendations on courses located in that particular sub domain. If none of these courses had been completed by others so far, the PRS randomly recommended one of them. If one course had already been completed by the learner the other course(s) was/were recommended. If all courses of the sub domain (e.g., ‘clinical’) were completed the ontology recommended a course that was part of the top domain ‘Environmental Psychology’.

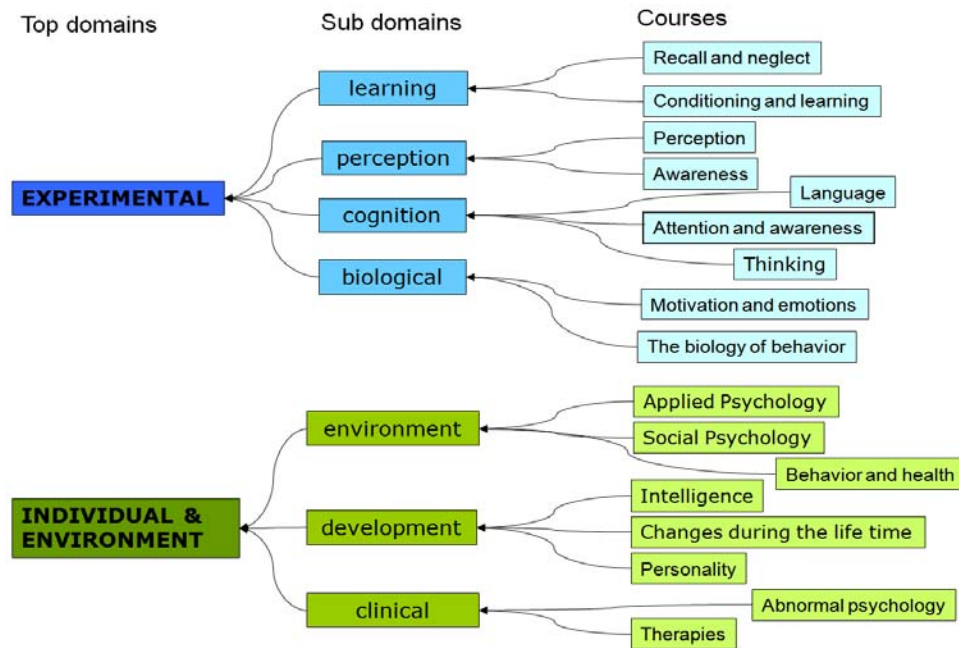


Figure 3: Structure for ontology based recommendations

Procedure

The participants could voluntarily register for the new version of the course, and were informed that they were taking part in an experiment with a new learning environment. They were not informed that only half of the students would receive additional navigation support. The participants were randomly assigned either to the experimental group or the control group. Both groups received the same treatment (course materials); all were able to ask questions to a tutor in a forum. In order to draw conclusions to self-organised informal LNs both groups got a maximum of freedom for their studies. Both groups were informed that they did not have to follow the LAs in a certain order or pace. In principle they were able to study the course over years.

As a consequence not all students started their study in October; some of them started later, (dynamic starting point). Furthermore, they were allowed to complete LAs at their own pace. Students could register for a final exam whenever they wanted, even without completing any of the multiple choice online progress tests available. The experiment ran for four months, from early October 2006 until late January 2007. During this period no further information about the experiment was given to the participants. In the experimental period of four months, measures were taken every two weeks.

Analysis of Effectiveness and Efficiency

In order to deal with a selection problem in our experiment we defined a goal attainment of 5 completed LAs out of 17 in total. Our aim was to support as much learners as possible to complete these 5 LAs as fast as possible. To measure the effectiveness and efficiency of the PRS learners were taken into account that applied to the following

rule; completed more than 5 LAs, or successfully completed the final exam, or were still studying at the measure point. This rule leaves a number of 101 students at the end of the experiment (n=52 in the experimental group and n=49 in the control group). Regarding the individual dynamic starting points of the students the recorded measure in Table 1 contained 0 values in case students started later (see Table 1). In order to ran a MANOVA analysis all individual starting points of the students were moved in one 'starting' column through deleting the 0 values. Therefore, Table 1 was transformed into a study progress table (see Table 2). Table 2 differentiate from Table 1 through moving the individual starting points into one 'starting' column (first column), and the duplication of the study results towards the end of the Table 2 if the students applied to the above mentioned rule.

Table 1. Example table of biweekly recorded measures

| Learner | Biweekly measure | | | | | | points |
|----------|------------------|--------------|------------|--------------|------------|--------------|------------|
| | Oct | Oct 2 | Nov | Nov 2 | Dec | Dec 2 | Jan |
| 1 | 1 | 2 | 4 | 7 | 7 | 7 | 8 |
| 2 | 0 | 0 | 0 | 1 | 3 | 5 | 9 |
| 3 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 4 | 1 | 2 | 3 | 4 | 4 | 4 | 4 |

Note: This table represents the 'raw' recorded measures of the biweekly measure points. The 0 values are related to the individual starting point of the participants.

Table 2. Example table of prepared biweekly measures for MANOVA analysis

| Learner | Study | progress | per | learner | per | measure | point |
|----------|----------|----------|----------|----------|----------|----------|----------|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 1 | 1 | 2 | 4 | 7 | 7 | 7 | 8 |
| 2 | 1 | 3 | 5 | 9 | 9 | 9 | 9 |
| 3 | 1 | 1 | | | | | |
| 4 | 1 | 2 | 3 | 4 | 4 | 4 | 4 |

Note: This table shows the actual study progress of all active learners. Therefore, all 0 values from Table 1 are deleted and the individual starting points were moved into one 'starting' column (first column).

To test hypothesis 1 and 2, we analyzed the measures taken using SPSS 12. To avoid inflated Type I error due to multiple tests, a priori tests of specific contrast scores were used. The effectiveness and efficiency was analyzed by means of linear and quadratic trend analysis. Averaged completion scores and averaged completion time during the two experimental periods were transformed into linear and quadratic trend contrast scores by means of computation of orthogonal polynomials. We applied multivariate analysis of variance (MANOVA) for repeated measures on these a priori chosen contrast scores with Group as between subjects factor and Time (or Progress) as within subjects factor. A significant interaction of contrast scores with Group was followed by testing of simple contrast effects. Due to the a priori character of these tests, they were performed with the conventional Type I error of .05 (Tabachnick & Fidell, 2001).

Analysis of variety of learning paths

To test hypotheses 3, the variety of learning paths, we analyzed the behaviour of the learners with a Graph Theory approach (Gross & Yellen, 2006). Therefore, we modelled the LN in Netlogo 4 (Tisue & Wilensky, 2004), and observed the completion of LAs by the learners. If a learner completed for instance first LA 1 and second LA 7 it was counted as traffic between LA 1 and LA 7. A line was drawn between both LAs in the graph when the traffic became larger than 3. If the learning path was used even more frequently, the traffic line got thicker and changed its colour. Consequently, the thickest path was used most often and the thinnest path was used only three times.

Analysis of satisfaction with the PRS

To test hypothesis 4, the general satisfaction of the PRS, we conducted an online recall questionnaire. This questionnaire was sent to all 190 participants in both groups at the end of the experiment. We received answers from 52 people in total, thus we had a response rate of 27%. From the control group 24 out of 92 learners responded and from the experimental group 28 out of 98 learners. The response rate of the control group was 22% and the response rate of the experimental group was 27%.

Results

Effectiveness

The amount of progress made by learners in both groups as indicated by the number of LAs completed after four months (half-way) of the experiment is represented in Figure 4. The overall completed LAs (the overall progress of both groups) over time was denoted by a significant positive linear trend ($F(1,99) = 203.22$, $p < .001$) and a significant positive quadratic trend ($F(1,99) = 40.31$, $p < .001$). There was no significant effect of Group for effectiveness on the linear and quadratic trend.

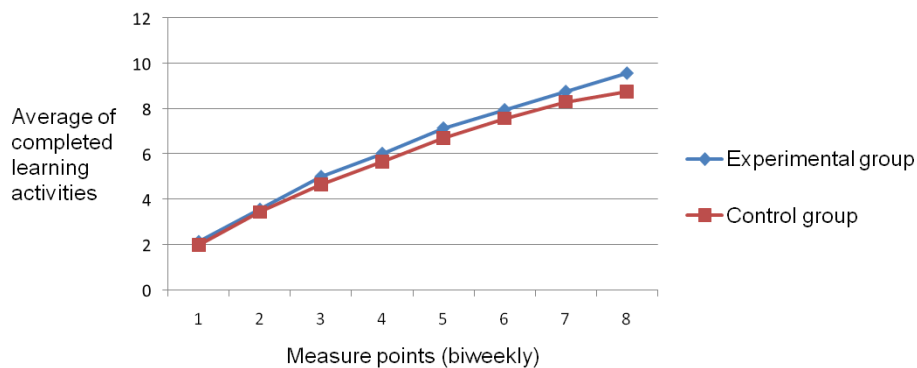


Figure 4: Progress of learners on completion of courses during the experimental period

Efficiency

The time learners spend after four months is represented in Figure 5. The overall effect of time was denoted by a significant positive linear trend ($F(1,99) = 101.32$, $p < .001$) and a significant positive quadratic trend ($F(1,99) = 4.3$, $p < .05$). The experimental group, needed constantly less time to complete equal amounts of LAs. This result was also confirmed by SPSS with a significant effect of Group on the quadratic trend ($F(1,99) = 5.14$, $p = .026$). No significant effect of Group was found on the linear trend. Simple effects analysis showed that for the control group the curve got a declining trend at the end, whereas the experimental group behaved increasingly linear.

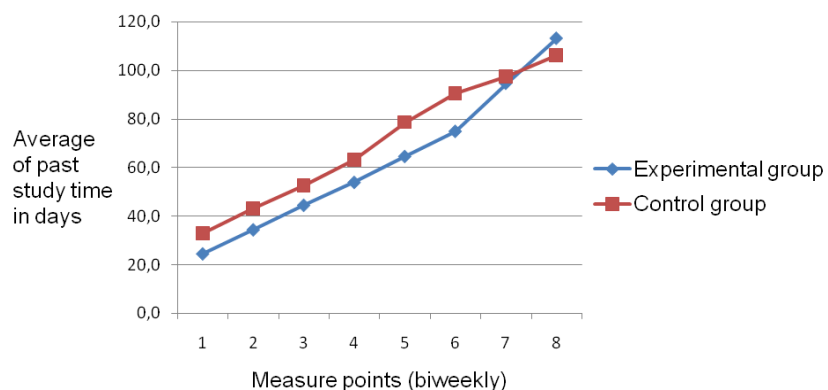


Figure 5: Average study time during the experimental period

Figure 6 shows how often the recommendations techniques were used during the experiment in the distributed and cumulated values. During the first month the cold-start problem of the PRS occurred, because there was no data available for stereotype filtering. Nearly all recommendations in this period were covered by ontology-based recommendations. But starting from the second month, stereotype filtering has been used more often and became equally used, when we consider distributed numbers at the end of the experiment.

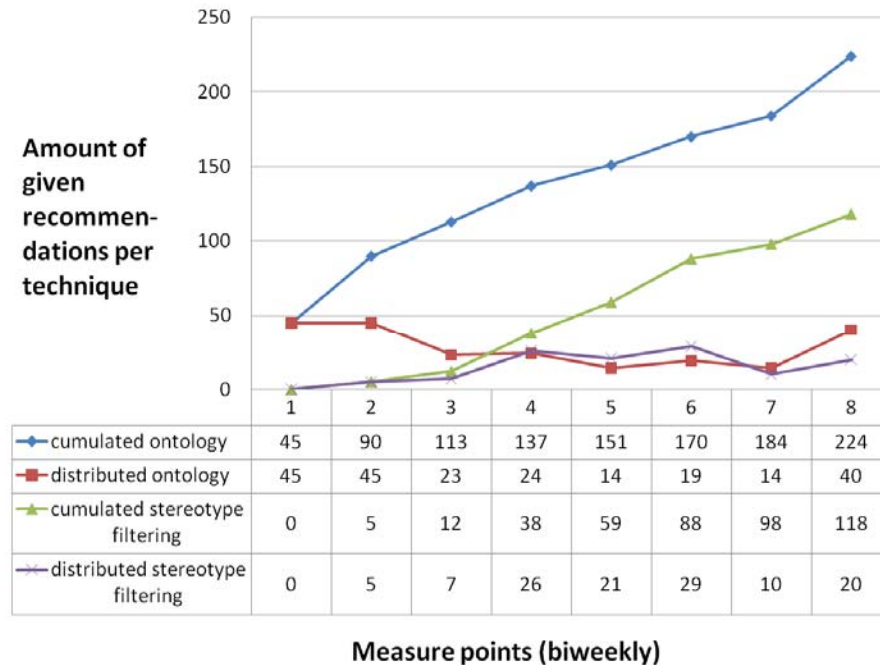


Figure 6: Usage of recommendation techniques during the experiment

Variety of learning path

To compare the emerged learning paths of both groups we placed all LAs in Netlogo 4 in a circle. LA 1 is the starting chapter of the additional given book labelled as the ‘biology of psychology’. The numbers attached to the nodes in the graph mark the chapter number from the additional given psychology book. Figure 7 presents the emerged learning paths of the control group, and Figure 8 presents the emerged learning paths of the experimental group. Both Figures were drawn with the recorded user behaviour at the end of the experiment.

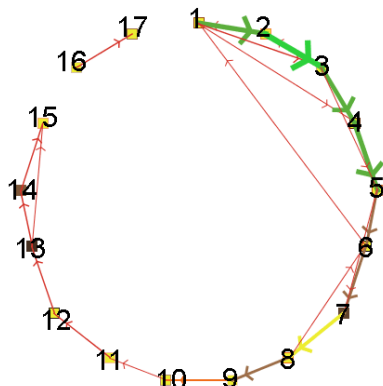


Figure 7: Emerged learning path of the control group at the end of the experiment

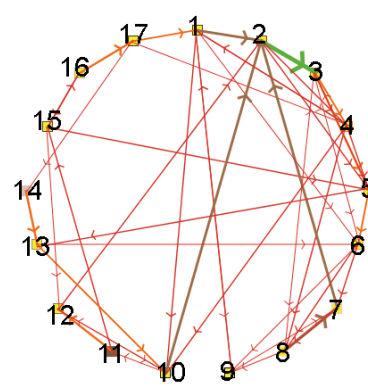


Figure 8: Emerged learning path of the experimental group at the end of the experiment

For the control group we see (Figure 7) that most of the participants followed the order of the textbook that was given to the Moodle environment. For the experimental group (Figure 8) many more thin and medium size lines reflect the influence of the PRS. The participants in the experimental group have taken more personalised learning paths than the control group. They hardly followed the chapter order of the textbook.

Satisfaction with the PRS

In this section we present the most relevant answers from the online recall questionnaire of the experimental group regarding the satisfaction of the PRS. We also asked for the general usage of the PRS as an indicator for satisfaction. The results of the questions about the general use can be found in Table 3. The more detailed questions about the satisfaction are shown in Table 4.

In Table 3, Question 1 it is shown that 64% (n=18) of the participants used the PRS during the whole period, 4% (n=1) did not use it the whole time because the explanation of the recommendation was not clear enough for them, and 32% (n=9) answered that they did not use the PRS the whole period because they also wanted to follow the book. For question 2 46% (n=13) answered that the PRS helped them to organise the study in a more personalised way, whereas 54% (n=15) of the learners answered that the PRS did not help them to organise their study in a more personalised way.

Finally, the learners were asked about their 'obedience' to the system, i.e., how often they follow up on the advice that was given to them (Table 3, question 3). 32% (n=9) answered they had followed the advice very often, and 29% (n=8) answered they had followed the advice often. 11% (n=3) were neutral to this question and around 29% (n=8) answered that they seldom / or very seldom had followed the advice.

We were also interested if the PRS followed the expectation of the learners (Table 4, Question 1). 14% (n=4) / 21% (n=6) of the learners answered that the recommendations followed their expectations (i.e., what they themselves wanted to do next) very good / good. 61% (n=17) were neutral about the PRS and only 4% (n=1) answered that the PRS was less in line with their expectations.

Table 3. General question about the usage of the PRS from the experimental group (n = 28)

| Question | Values | | | | |
|--|------------|-----------------------------------|---|--|-------------|
| | Yes | No, because of technical problems | No, because the description of the recommendations were not transparent to me | No, because I also wanted to follow the book | |
| Did you use the recommender system during the whole period of the course? | 64% (n=18) | 0% (n=0) | 4% (n=1) | | 32% (n=9) |
| | Yes | No | | | |
| Do you think the PRS helped you to structure the learning activities in a more personalised way? | 46% (n=13) | 54% (n=15) | | | |
| | Very often | Often | Neutral | Seldom | Very seldom |
| How often did you follow the recommendation that was given to you? | 32% (n=9) | 29% (n=8) | 11% (n=3) | 11% (n=3) | 17% (n=5) |

To further analyse the impact of our recommendation strategy, we asked the learners if they were more satisfied with the recommendation given in the beginning or at the end of the experiment (Table 4, questions 2 and 3). We wanted

to know if the learners noticed any differences in the given recommendation over time, since the ontology recommendation was mainly used in the beginning of the learning progress and the stereotype filtering technique was used mainly at the end of the learning progress. Surprisingly, the learners rated their satisfaction for both periods quite different. 7% (n=2) and 18% (n=5) were positive about the recommendations during the first two month (ontology). But 7% (n=2) and 39% (n=11) rated the last two month more satisfying. It seems that they are more satisfied with recommendations based on the stereotype filtering. A minor percentage 4% (n=1) and 7% (n=2) were less satisfied with the recommendations. Nevertheless, nobody was unsatisfied with the recommendations.

Table 4. Detailed responses about the benefit of the PRS from the experimental group (n = 28)

| Question | Values | | | | |
|--|--------------|---------------|---------------|-------------|-------------|
| | Very good | Good | Neutral | Less | Very less |
| Did the recommendation of the recommendation system follow your expectations for studying the next learning activity? | 14% (n=4) | 21% (n=6) | 61% (n=17) | 4% (n=1) | 0% (n=0) |
| How satisfied have you been with the recommendation given by the recommendation system during the first two month of your studies? | 7% (n=2) | 18% (n=5) | 71% (n=20) | 4% (n=1) | 0% (n=0) |
| How satisfied have you been with the recommendations given by the PRS during the last two month of your studies? | 7% (n=2) | 39% (n=11) | 46% (n=13) | 7% (n=2) | 0% (n=0) |

Conclusions and Discussion

Based on the results of the experiment we can draw several conclusions for our research on navigational support in self-organised, informal LNs for lifelong learners. According to our 4 hypothesis, we can now conclude the following.

Effectiveness

The experimental group was consistently found to be more effective in completing LAs than the control group during the experimental period. Even with these promising observations, we have not found a significant difference; therefore, hypothesis 1 cannot be confirmed. It might be that this is due to the fact that the experimental period was to short and further observations might be more successful.

Efficiency

The experimental group consistently needed less time to complete equal amounts of LAs, which effect was found to reach significance after 4 months. Therefore, hypothesis 2 could be confirmed. This result shows that our approach to navigational support and our recommendation strategy enhance the efficiency of learners in self-organised, informal LNs.

Variety of learning paths

The variety of personalised learning paths increased by the PRS. The experimental group from the beginning onward created more personalised learning paths. Some of these personalised learning paths also caused (by emergence) successful learning paths taken by other learners. Considering this results in combination with the positive effect on efficiency and satisfaction it appears that the personalisation and the support of self-organisation in informal LNs were beneficial for the learners. The experimental group outperformed the control group and used the PRS. Based on this result we also confirm hypothesis 3.

Satisfaction

The qualitative data about satisfaction from the recall questionnaire underlined the quantitative results about the actual use of the PRS. The learners accepted the PRS for supporting them in their self-organised navigation through the LAs. 64% of the participants used the PRS over the whole experimental period very often or often. 46% have the impression that the PRS helped them to organise their learning progress in a more personalised way. The experimental group was more satisfied with the recommendations based on stereotype filtering. This is an interesting finding and will have influence on our future research. Regarding the informal characteristic of LNs, we want to use more bottom-up techniques like collaborative filtering instead of top-down ontologies. In future research we are planning to combine these bottom-up techniques with learner ratings and tags, which have been proven to be appropriate for self-organisation in informal environments like LNs. However, because of the positive responses from the learners and actual usage data we can confirm hypothesis 4.

Limitations and future research

We have reported positive outcomes to our study. However, we have to point the reader to some serious limitations as well. Besides the limitations already mentioned in the previous result section, there are some more general limitations to this study, regarding the experimental design we applied.

First, although our research addresses lifelong learners in self-organised and informal LNs, the practical character of the experiment, embedded in a formal course with real students that wanted to be accredited, excluded some of the navigational and motivational problems faced by lifelong learners. For the future research of LNs we envision more informal learning activities without a formal assessment, therefore we are planning to have an additional experimental pilot where open educational resources (OER) and their communities are used. An experimental pilot with OER is more similar to LNs, thus a LN could exist out of different mixed OER, formal learning offers, or separated learner contributions in once.

Second, the experimental setup did not force learners to actually take the recommended next step, and we do not know to what extent learners actually followed up the advice. The problem is the definition of what constitutes a ‘followed recommendation’. Did learners follow a recommendation when they navigated to a recommended LA? Or did learners follow a recommendation when they stayed longer than 5 minutes in the recommended LA? As a result, the improved efficiency cannot be unambiguously ascribed to the PRS itself. The mere presence of a navigation support tool may have stimulated the experimental group. An additional experiment involving a control group receiving random recommendations would help clarify this point. We were not able to provide faked recommendation to the control group because of ethical reasons. It would have been not fair to confuse the control group with random recommendations, because they also were real students that paid the same amount of money for the course.

Third, we have to mention one limitation for effect on efficiency. There is a difference between the measured ‘elapsed time’ that students took to complete a LA and the actual ‘study time’ they needed to successfully complete a LA. Elapsed time as measured through the Moodle environment is an assistant indicator for real study time.

Finally, we decide to show only the ‘best next LA’, based on our recommendation strategy to the learners. We did that for experimental reasons, otherwise the analysis would have been even more complex. Alternatively, we could have given both groups the same user interface with all the LAs listed, the only difference being that in the experimental group the LAs are reordered according to the recommender system’s priorities while the control group gets a standardised ordering. This would have provided a more similar environment for both groups, but also might force the learners to select always the first LA on the list. Nevertheless, in real life a list or a sequence with suitable recommendations on different characteristics might be more valuable for the learners than a single recommendation.

Further research is needed to address these limitations and to reveal whether alternative recommendations would have a greater impact on effectiveness, efficiency, variety, and satisfaction for lifelong learners in self-organised LNs. Additional information given to the recommendation of a LA could be success rates, required competence levels, average amount of study time, subjective ratings, or tagging information given by other learners.

Currently we are running a series of simulations in Netlogo where we test the impact of different other recommendation techniques and their combination in recommendation strategies for different sizes of LNs. Despite the limitations of the presented study, we believe it (at least partially) proves that the use of navigation support based on a personalised recommendation strategy offers a promising way to advise learners on their self-organisation in LNs.

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Analysis of Peer Interaction in Learning Activities with Personal Handhelds and Shared Displays

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ABSTRACT

Collaborative learning is extensively applied in classroom activities, but the screens on handheld devices are designed for individual-user mobile applications and may constrain interaction among group learners. The small screen size may lead to fragmented and tête-à-tête communication patterns and frequently obstruct the externalization of the learning process. This study compares two learning scenarios, one using only handheld devices and the other integrating handheld devices with LCD shared displays, in order to explore whether shared displays in classrooms can augment handheld devices to facilitate articulation and communication among participants. This study involved 15 graduate students enrolled in a Statistics and Data Mining course. Data were collected on the course over a period of eight weeks. Students were required to solve problems collaboratively and content analysis was performed on student dialogue and nonverbal interactions in the two different learning scenarios. In the environment with shared displays, each discussion thread attracted more students and demonstrated more shared visual focus than in the one-to-one setting by a significant margin. Students, when studying in an environment with shared displays, exhibited more lively interaction with each other, including frequent hand-pointing behavior. Furthermore, students proposed more arguments and positions in the Shared-Display environment than in the environment without shared displays. Therefore, shared displays can not only improve articulation processes, but can also promote student engagement by establishing a social workspace for learning with handheld devices.

Keywords

Interaction analysis, handheld devices, CSCL, shared display, groupware design

Introduction

The ratio of computers to students in classrooms is rising steeply as the price of handheld devices such as PDAs, laptop computers, and Tablet PCs decreases. The ratio of one computer per student is increasingly becoming a reality in some schools, creating the one-to-one (1:1) computing environment (<http://www.g1to1.org/>). In classrooms equipped with wireless networks, technology is beginning to enrich conventional classrooms and enhance the learning and teaching practices within them. Handheld devices have been utilized to support lively learning, create rich learning scenarios in such technology-enriched classrooms, and encourage socially promotive interaction (Roschelle, 2003; Zurita & Nussbaum, 2004; Liu et al., 2006). However, handheld devices are designed for personal applications, rather than collaborative scenarios. Whether handheld devices facilitate or impede face-to-face social interaction is an important research issue (Hwang, Tsai & Yang, 2008).

Creating a situation and space that enables students to interact and learn is the main concern of design-based research (Collins, 1992). Design-based research is a series of approaches with the intent to produce new theories, artifacts, and practices that account for, and potentially impact, learning and teaching in naturalistic settings (Barab & Squire, 2004). Even though there is always a need to construct an environment of interaction, design-based research investigates how students learn in their learning environment and revises and optimizes the design of the environment accordingly (Barab et al., 2001). Recently, most studies focus on learning scenarios in which students learn and interact with peers solely through handheld devices. Although the resultant information is necessary to the construction of a space for students to learn in a 1:1 environment, few studies have as yet investigated how students interact with each other when provided with a combination of handheld and peripheral devices. There remains,

therefore, a need to understand the situation in which collaborative learning can be effectively implemented in a 1:1 computational environment.

Peer discussion and interaction have been found to facilitate collaborative learning. Collaborative problem solving has gained significant attention among educators for improving student learning (Dillenbourg & Traum, 2006; Liu & Kao, 2007). Instead of passively receiving knowledge from teachers alone, students can engage in problem solving and knowledge construction activities during peer discussion and interaction (Blumenfeld, Marx, Soloway, & Krajcik, 1996). However, 1:1 learning scenarios sometimes overemphasize the affordance of handheld devices to facilitate face-to-face collaboration, particularly if the scenarios disregard the fact that cognition may be distributed among various artifacts including large displays, whiteboards, printers, and learners in the classroom (Hutchins, 1995). Therefore, the analysis of peer interaction plays a significant role in the understanding of the critical learning process and the effectiveness of peer collaboration in a 1:1 computing environment.

Collaborative learning activities encourage members to share the learning experience, gather learning resources to help others, and share learning achievements. Extensive collaborative learning systems have been developed on computers and the Internet to enhance learning (Suthers, 2005, Liu & Tsai, 2006). Despite the significant advancement of online collaboration, educators still emphasize the importance of face-to-face collaboration, because promotive interaction is a critical factor in the success of cooperative learning (Johnson & Johnson, 1994). Additionally, face-to-face interaction is the most common interaction style in classrooms. The interaction of students with their peers through different technological devices, and the influence of these devices on interaction among students, have become important research issues as technology gradually comes into classrooms. Researchers have analyzed conversations between students in online collaborative learning scenarios to investigate how students interact in online discussion forums (Scardamalia, 2004; Liu & Tsai, 2006). Nevertheless, face-to-face collaboration has many interaction cues, such as visual focus and hand-pointing behaviors, which are not visible in online peer interactions. Therefore, the development of an appropriate methodology is necessary to reflect and explore correctly the effects and atmosphere of face-to-face peer interaction. Consequently, this study attempts to investigate the peer interactions involved in face-to-face collaborative learning with handheld devices.

The effects of human activities may depend on the designs of the technological devices used and on the settings in which these devices are applied. For example, when students are performing collaborative activities with individual tabletop computers, the lack of shared displays may lead to a loss of eye-contact and an unawareness of visual focus (Scott et al., 2003). The screens of handheld devices may be counterproductive to the promotion of interaction among groups of learners, thereby causing difficulty in establishing effective peer interaction during collaborative activities. Meanwhile, display technology has significantly changed human application of information technologies in recent years. Liquid Crystal Displays (LCD) are becoming increasingly cheap and popular peripheral devices. Institutes and organizations increasingly set up LCD devices in public areas. They are increasingly important peripheral devices, working with personal devices to support group work and learning. The LCD becomes a shared display to augment group learning in the 1:1 computing environment. Therefore, this study examines how students interact with handhelds and how shared displays in classrooms affect peer interaction in face-to-face collaborative learning.

One salient feature of social collaboration and presence is intimacy, which depends significantly upon non-verbal cues such as eye contact and smiling (Short et al., 1976). A mutual gaze moderates interpersonal distance and the sense of intimacy (Argyle & Dean, 1965). In addition, gesticulated interaction frequently takes place along with verbal utterances in meaningful processes, resulting in meaning creation (Klerfelt, 2007). Scott et al. (2003) analyzed the non-verbal interpersonal interactions of group members during discussion, in order to assess whether the current collaborative learning environment setting is beneficial to discussion. This study proposes an analytical scheme to investigate how environments influence interpersonal collaborative interaction in terms of participation, non-verbal social cues, visual focus, and a conversation log. The following research issues, based on interaction analysis, are considered:

- Research question 1: How the process of participation and negotiation differs when the collaborative activity is supported by a 1:1 computing environment and shared displays?
- Research question 2: How social interaction differs when collaborative activity is supported by a 1:1 computing environment and shared displays?
- Research question 3: How the argument process differs when collaborative activity is supported by a 1:1 computing environment and shared displays?

One-to-one and shared display groupware

The portability and communication capabilities of handheld devices enhance classroom dynamics and promote face-to-face interactions (Zurita & Nussbaum, 2004; Liu & Kao, 2007). Students engaged in collaborative problem solving activities need both personal workspaces for doing their own work and a public workspace, where they can share personal work and discuss group work together. Many collaborative learning models, such as Think-Pair-Share (Lyman, 1981) and Jigsaw (Aronson, 1975), can adopt personal and public workspaces to enforce personal accountability and shared group goals respectively (Lai & Wu, 2006). However, handheld devices are designed for individual-user mobile applications, rather than for collaborative applications, and may therefore restrict face-to-face collaborative learning interaction. Due to the small screen size of handheld devices, students intuitively interact most frequently with the peers located adjacent to them, while neglecting peers sitting further away. The lack of public workspace may impede communication among members and lead to *tête-à-tête* or fragmented communication patterns (Milson, 1973).

To investigate how shared displays affect collaboration socially, this study provided a technology-enriched collaborative classroom (Figure 1) with shared display groupware, including six LCD displays, as a public workspace, while students performed their personal learning tasks using handheld devices. All displays in a classroom were connected to a shared display groupware system with which students could edit documents, search the Internet for learning materials, and send their ideas, as well as upload documents onto the shared display groupware. The groupware also allowed students to project their handheld screens onto the shared display via a wireless network (Figure 2).

The shared display groupware for each of the LCD displays in the classroom was based on client-server architecture and was designed in three layers: the network layer, the individual workspace layer, and the coordination and presentation layer (Figure 2). The network layer enabled students to connect the shared display groupware and individual handheld devices through the TCP/IP and wireless network. The individual workspace layer provided an interface on the student handheld devices (client) for editing their documents and searching for learning materials from the Internet and also allowed students to send their ideas and upload documents onto the shared display groupware (server). The coordination and presentation layer (Figure 2) provided those functions necessary for students to interact with the shared display server. With the functionality provided by the coordination and presentation layer, students could project their handheld screens onto the shared display via a wireless network, enabling them to share ideas and documents on the shared display instead of the small screen of the handheld devices.

Buxton's "less is more" design principle (Buxton, 2001) asserts that the key issue of design is to focus less on technology and engineering and far more on the human element. Adding technological functionality to the tools or channels between humans does not always add value to those tools for the mediated people. For example, in Buxton's article, the Super Appliances 5-in-1 power tool and Swiss Army Knife that integrated many functions in a single tool did not always guarantee a value-adding effect on these tools (Buxton, 2001). Thus, there is a need to examine the human reactions when shared displays are added to 1:1 computational environments.

Most studies have confirmed that the affordance of individual devices in learning scenarios, clickers and PDAs for example, do improve interaction in the classroom (Roschelle, 2003; Zurita & Nussbaum, 2004). Adding shared displays to collaborative learning scenarios, however, could possibly cause problems with distraction, because students would then have to switch between different workspaces and screens. The shared displays could also possibly result in problems with competition for control among students, because there is only one input device (i.e. one mouse and keyboard) for each shared display. Therefore, shared displays do not inevitably have a beneficial effect on collaboration. There is clearly a need to examine students' reactions to the integration of handheld and peripheral devices.

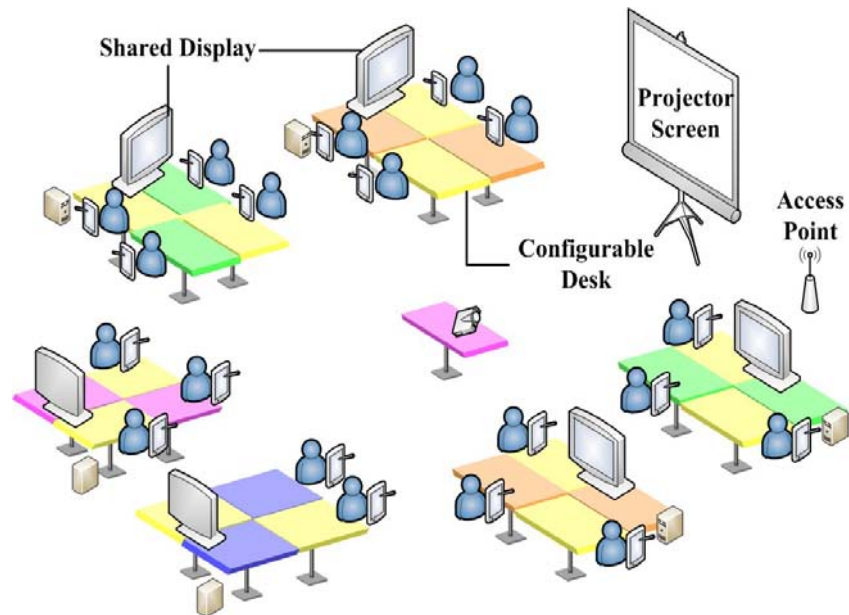


Figure 1. The technology-enriched collaborative classroom

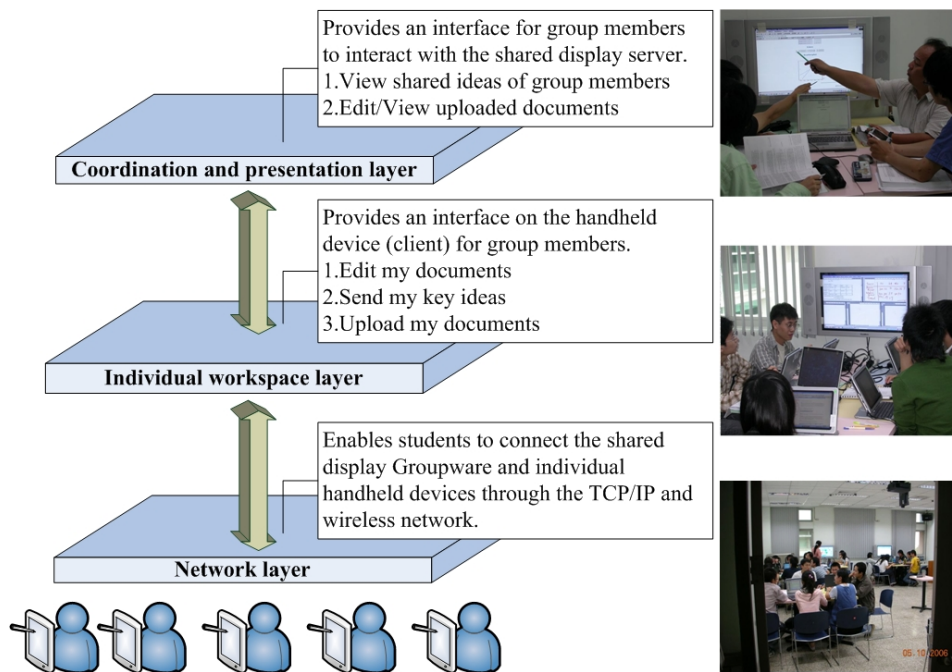


Figure 2. The shared display groupware architecture

Method

The environment necessary for mobile learning research generally requires a significant equipment investment, such as Tablet-PCs, PDAs, and peripheral devices. It is difficult to conduct studies on large numbers of students. Many mobile learning studies (Zurita & Nussbaum, 2004, Liu & Chou et al., 2006) follow the design-based research approach (Collins, 1992). Because this approach involves rich, collaborative social interaction in a real world, not all variables of interest are well known in advance. For this reason, design-based research emphasizes finding and identifying specific phenomena that improve the learning environment and student practice, rather than just reporting

the learning outcomes of controlled experiments. This type of study investigates learning practices deeply, revealing an advisable direction of further research. It focuses on the explanations for certain phenomena and closely examines communication and collaboration patterns. The intent is to determine why and how certain behaviors happen under specific conditions and to generalize these findings to apply to more loosely related cases.

Participants and the course

The participants were fifteen graduate students enrolled in the course "Statistics and Data Mining Techniques," at National Central University (Taiwan). The class was composed of weekly 3-hour classes and was focused on statistical analysis and data mining. During each class, the teacher first outlined each week's learning content. A student then presented the learning content related to the topics assigned. Students then began to solve the problems assigned by the teacher collaboratively after the student presentations. This study assessed peer interaction as influenced by the use of different equipment in the classroom. Thus, the experiments were carried out in two different environmental settings, namely 1:1 and Shared-Display. In the 1:1 setting, students used only the Tablet PC for both individual learning tasks and collaborative learning activities in the classroom. In the Shared-Display setting, students could utilize shared display groupware as well as handheld devices. The entire experiment lasted eight weeks.

Collaborative problem solving activity

The students were divided into 3 groups of five. In practice, the number of students participating in the collaborative learning activities varied between three and five, because some students did not attend some of the classes during the experiment. The teacher presented problems, which the students had to collaborate to solve. To enforce personal accountability, students had to solve the given problems by themselves before discussing them with their peers. Students had appropriate resources at their disposal in the classroom for solving the problems, such as statistical tables, calculators, and Microsoft Excel. Along with the resources available in the classroom, students also had to search Internet resources, such as statistical tools, to solve complicated problems. Group members then conferred with each other to organize a group solution, each had submitted a personal solution to the given problem. The interaction between group members and the process of discussion was observed in order to gain an understanding of how they interacted with the aid of handheld devices.

Argument process analysis

During collaborative learning activities, students have to express and discuss divergent ideas in order to construct and share knowledge collaboratively. In a face-to-face collaborative learning scenario, all these communications occur in the conversation among group members, because each member is required to externalize his/her ideas. Conversation is an important tool for knowledge mediation within a culture (Säljö, 2000). Conversation, negotiation, and the sharing of perspectives are carried out to build knowledge (Suthers, 2006; Stahl, 2005). A graphical representation, based on chat log analysis framework (Stahl, 2005), was adopted for this study to identify the role of uptake within online discussion forums. However, when students are solving complex problems collaboratively, they rely on a domain-specific argumentative model to solve problems within a domain. For example, design-based problems involve issue generation and position expression to solve complex problems. "Uptake" is therefore, is too general a term to describe the structure of discussion for the specific domains.

This study applied IBIS (Kunz & Rittel, 1970) as a model to analyze collaborative problem solving activity, rather than as a structure for discussion. In face-to-face interaction, there were rich physical gestures and facial cues during group discussion, which cannot be expressed in online communication. IBIS involves only task-oriented information (i.e. issue, argument, and position). It does not involve the social aspect of activities, such as the group development process and social cues. Therefore, this study proposed a methodology that combines conversation and social cues to explore face-to-face group discussion. Utterances within student conversations were sorted into the following categories based on their purpose in the problem solving process (Liu & Tsai, 2006):

- **Issues:** What needs to be done and what questions need to be answered. Issues relate to the concepts and skills being learned by students. For instance, students may seek peer support in solving a learning problem by asking questions such as “How about your decision on *fe* (formula)?”, or “How did you solve Question 1?”
- **Positions:** Methodologies for resolving an issue or a question. Positions constitute answers from peers in response to issues that have been raised. A student may help others by responding to issues with comments such as “The answer is normally written like this”, or “Your answer to 5.56 is unlikely to be correct.”
- **Arguments:** Opinions that support or oppose a position. For instance, students may comment on the positions of others with statements such as, “So, let me explain it by giving an example: would the average scores of third-grade students in one junior high school be lower than the national scores?”, or “You can compare it with the second question, which is solved by the second method.”
- **Group development:** Suggestions for the progress of collaborative activities. For example, “I’ve found an example for solving the two-sample question”, or “We should apply the example in Question 1.”

Social interaction analysis

Non-verbal interpersonal behaviors facilitate interaction among group members in face-to-face collaborative learning (Short et al., 1976; Scott et al, 2003). Group members in this study did not restrict themselves to interaction through handheld devices. Instead, they could point at the shared display, make eye contact with each other to improve discussion, and watch each other’s responses. This study analyzed hand-pointing and visual focus behaviors to confirm how environments influence interpersonal interaction during collaboration. The video of each group was recorded individually and analyzed by two independent observers.

Analysis of participation and negotiation

To integrate non-verbal interaction with conversational analysis, this study codified the events that occurred during the collaborative problem solving activities in a group dynamic chart (Figure 3 and 4). The heading denotes the group members A, B, C, D, E, respectively. There are two columns representing conversational and non-verbal interactions. The left column represents the conversational interactions, the right column the non-verbal interactions. The Y axis represents the chronological order of the conversational utterances. Conversational interactions are depicted in the conversational interaction chart (the left sequence of each chart in Figure 3 and Figure 4). Each number denotes an utterance generated by the group members. Each dashed line in the chart denotes a response from a certain student (or the student’s) to another student’s conversational utterance. For example, student D provided position utterance 2 in response to student A’s group development utterance 1 in Figure 3.

In addition, the videos recorded of collaborative problem solving activity were analyzed to identify precisely how students interacted with the handhelds and with other students. Non-verbal cues demonstrating student visual focuses were identified using the videos. Non-verbal interactions are depicted in the non-verbal interaction chart (the right sequence of each chart in Figure 3 and 4). These non-verbal cues included (1) watching personal handheld devices, (2) pointing at personal handhelds, (3) watching the shared display, and (4) pointing by hand at the shared display. The visual focus cues are depicted on the right of the conversational interaction chart. For example, Figure 3 illustrates student B watching student A’s handheld device while student D was responding to student A’s group development statement with utterance 5. Students responded to other students’ issues, positions of discussion, arguments, and group development, and even to their responses, thus forming discussion threads. A new discussion thread was started when a student presented a new group development statement, position, or argument that was not related to previous discussion threads. The following interaction items were measured to investigate student interactions in discussion threads.

- *Discussion threads:* A discussion thread is a set of connected utterances made by students. For instance, utterances 1 and 2 in Figure 3 constitute a short thread, while utterances 3–21 form a long thread.
- *Thread depth:* The thread depth is the number of utterances students gave in a thread. The depth of the thread constituted by utterances 1 and 2 in Figure 3 is 2, and utterances 3–21 form a thread with a depth of 19.
- *Shared visual focus:* Students participating in a thread established shared visual focus by watching/sharing the screens of personal handhelds and by watching the shared display together. For example, students A and B established shared visual focus on student A’s handheld screen, because student B was watching student A’s

screen while student D was responding to student A with group development statement 5 in Figure 3. Another example is the establishment of shared visual focus on the shared display by all students while student A argued his opinion in argument 23 in Figure 4 with his hand pointing to the shared display.

- *Participants in threads:* This study examines student participation in discussion threads. A student was considered to be actively participating in a discussion thread when he presented opinions/responses or paid attention to other students proposing opinions or responses within the thread by having a shared visual focus with them. For instance, all students participated in the first discussion thread in Figure 4 (utterances 1–22) because all of them proposed opinions/responses. These students also actively participated in the second thread (utterance 23–25) even though only student A articulated his opinion, because all students had the same visual focus as student A.
- *Informed agreement:* Informed agreement indicates the number of students who actively participated in an activity and reached an agreement in a discussion thread. The participants of a thread were considered to have reached an agreement when some of them demonstrated their agreement by expressing opinions of agreement, supporting others' opinions, or by the non-verbal cue of nodding. For instance, four students demonstrated informed agreement in the thread starting with argument 61 in Figure 4, because student D nodded to support student A's argument when students A, C, D and E had established shared visual focus.

Criteria elicitation analysis

In order to understand user requirements and concerns regarding a system design, engineers gather direct user feedback through requirement elicitation (Browne, 2001). The elicitation process is integral to understanding individuals' conceptions of a design (Ford et al., 1993; Liu & Tsai, 2005). Therefore, the elicitation process could help in developing understanding of user perception and requirements regarding a building component. In order to investigate the student conception of the learning environment for the purpose of improving the design and, as a result, the learning, this study adopted a student-derived questionnaire as a means of elicitation. The information thusly gathered helps reveal students' concerns and requirements concerning 1:1 learning environments. The purpose of the questionnaire was not to perform a formal comparison between the Shared-Display system and 1:1 learning environment, but to understand, based on students' self-report, the important features that a 1:1 computational environment must have.

Students were required to fill out a questionnaire with questions in the form of the 5-point Likert scale, concerning their perception of the 1:1 and Shared-Display environments for collaborative learning activities. Working in their groups, the students developed questionnaires and then ask their peers to answer the questions. The Wilcoxon signed-rank test was used to test for differences. These questionnaires accurately reflect the students' concerns about effectiveness and design issues of the two environments, because they were produced by the students.

Table 1. The research questions, issues, and evaluation methods

| Research Questions | Issues | Evaluation methods |
|---------------------|--|------------------------------|
| Research Question 1 | Process of participation and negotiation | Group dynamic chart analysis |
| Research Question 2 | Social interaction | Non-verbal analysis |
| Research Question 3 | Argument process | Conversation analysis |

Data collection and data analysis

The design issues and evaluation methods regarding the research questions of this study are shown in Table 1. Data were collected by recording video and audio while students performed collaborative problem-solving activities in the classroom. This study analyzed a total of 102 minutes of discussion activity videos. All analyses of conversational and non-verbal interactions were performed by two independent researchers (coders). The analysis tasks included the classification of student conversation utterances, the identification of non-verbal cues, and the segmentation of conversations. The inter-coder reliability (agreement) for each analysis was at least 77%, indicating that the analysis was sufficiently reliable. Researchers resolved disagreements on analysis or categorization by discussion.

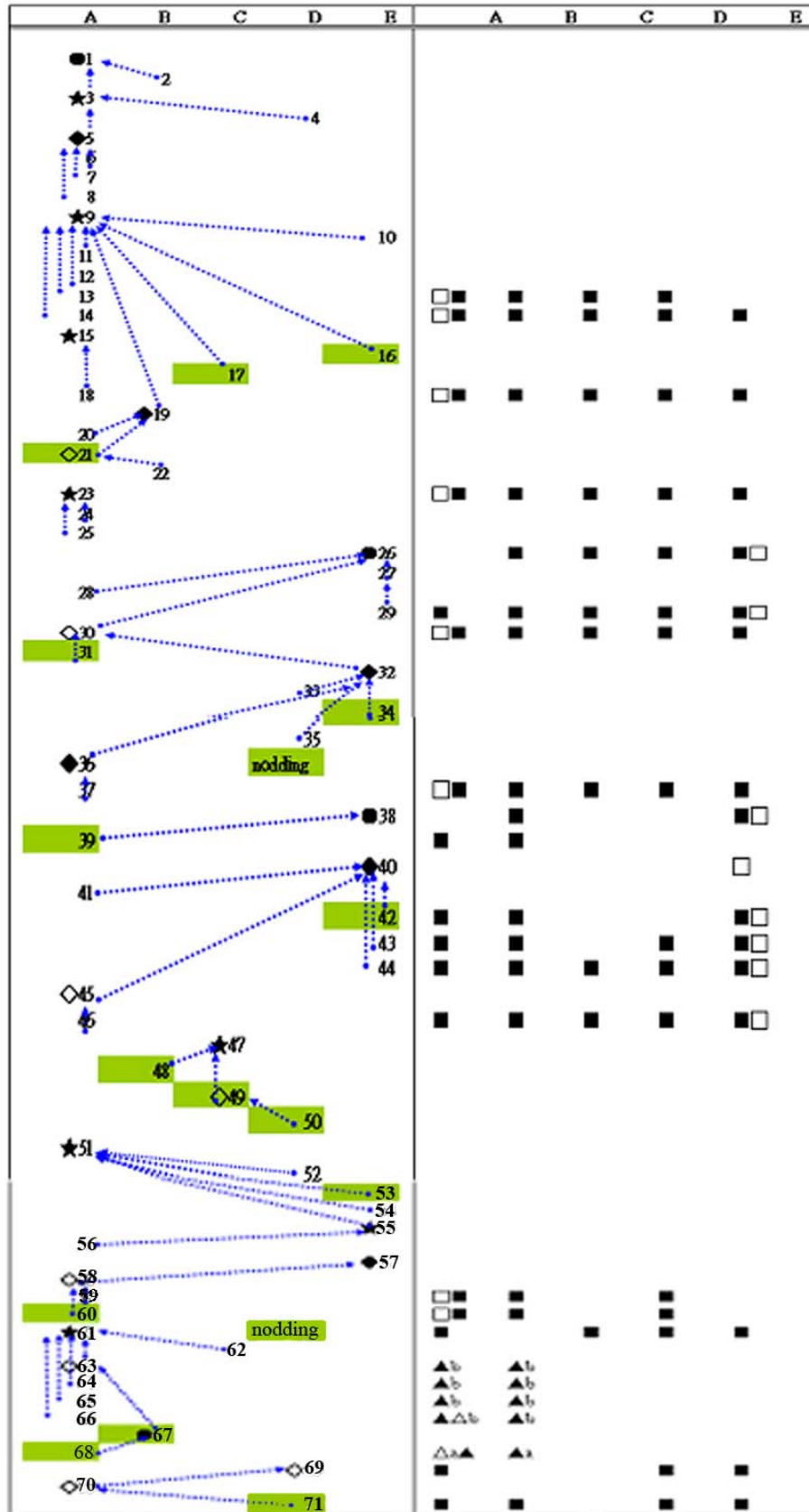


Figure 4. Group dynamic chart for a collaborative activity in the Shared-Display setting

Results and discussion

Results of analysis of participation and negotiation

Table 2 and Table 3 give an analysis of thread interaction, based on the group dynamics exhibited by the three collaborative problem solving groups in the two different settings. The number of discussion threads in which students engaged did not vary significantly between the two different settings. Students generated a total of 159 discussion threads, of which 81 occurred in the 1:1 setting and 78 in the Shared-Display setting. Moreover, the depth (i.e. length) of the discussion threads occurring in the 1:1 and Shared-Display settings was also similar, the average depth of a discussion thread being 4.21 in the 1:1 setting and 4.32 in the Shared-Display setting ($t=-.308$, $p=0.758$), as shown in Table 3. Students did, however, exhibit different degrees of participation in the two settings. In the 1:1 setting, an average of 2.20 students joined in each discussion. In other words, most interactions occurred between only two students. In the Shared-Display setting on the other hand, each discussion thread attracted the participation of an average of 2.97 students, significantly exceeding the thread participation rate of the 1:1 setting ($t=-5.777$, $p<.001$). The participative difference demonstrated by students in the two different settings reveals that the shared display encouraged students to interact with one another and engage in group problem solving activity.

Table 2. Statistics of participation, negotiation and social interaction

| | Group1 | | Group 2 | | Group 3 | | Total | |
|---|--------|--------|---------|--------|---------|--------|-------|--------|
| | 1:1* | Shared | 1:1 | Shared | 1:1 | Shared | 1:1 | Shared |
| Number of students | 5 | 5 | 4 | 5 | 5 | 4 | 14 | 14 |
| Number of threads | 27 | 21 | 23 | 14 | 31 | 43 | 81 | 78 |
| Average depth of threads | 2.85 | 3.38 | 6.04 | 6.43 | 4.03 | 4.08 | 4.21 | 4.32 |
| Average number of students participating in threads | 1.96 | 2.19 | 2.17 | 3.78 | 2.41 | 3.09 | 2.20 | 2.97 |
| Number of threads demonstrating shared visual focus | 4 | 12 | 8 | 11 | 13 | 37 | 25 | 60 |
| Average number of students showing shared visual focus in threads | 0.37 | 1.41 | 0.70 | 3.07 | 1.26 | 2.74 | 0.80 | 2.46 |
| Frequency of hand-pointing | 5 | 13 | 1 | 24 | 2 | 17 | 8 | 54 |
| Number of threads demonstrating informed agreement | 8 | 8 | 13 | 10 | 18 | 20 | 39 | 38 |
| Average number of students showing informed agreement in threads | 2 | 2.25 | 2.31 | 3.9 | 2.67 | 3.05 | 2.41 | 3.11 |

*1:1 represents one-to-one setting

Table 3. Difference test between 1:1 and Shared-Display environments

| Difference test of depth of threads | | | | | |
|--|----|------|------|---------|---------|
| | N | Mean | SD | t-value | p-value |
| 1:1 | 81 | 4.21 | 3.48 | -.308 | 0.758 |
| Shared | 78 | 4.32 | 2.82 | | |
| Difference test of number of participants in threads | | | | | |
| 1:1 | 81 | 2.20 | 0.86 | -5.777 | .000*** |
| Shared | 78 | 2.97 | 0.84 | | |
| Difference test of number of students showing shared visual focus in threads | | | | | |
| 1:1 | 81 | 0.80 | 1.34 | -7.323 | .000*** |
| Shared | 78 | 2.46 | 1.52 | | |
| Difference test of number of students showing informed agreement in threads | | | | | |
| 1:1 | 39 | 2.41 | 0.82 | -3.627 | .001** |
| Shared | 38 | 3.11 | 0.86 | | |

p<0.01, *p<0.001

Students demonstrated different degrees of informed agreement in discussion threads depending on their setting. A comparison of the discussion threads in the 1:1 and Shared-Display settings indicates that students exhibited informed agreement behaviors in nearly equal numbers of discussion threads in the two settings (i.e., 39 and 38 respectively). However, more students were involved in the informed agreement occurring in the discussion threads in the Shared-Display setting than in the 1:1 setting. On average, 3.11 students were involved in the interaction threads when informed agreement was reached in the Shared-Display setting. Conversely, students in the 1:1 setting generally only reached informed agreement with the peers sitting immediately adjacent to them. Consequently, an average of only 2.41 students reached informed agreement in discussion threads in the 1:1 setting ($t=-3.627, p=.001$). This finding indicates that, in order to facilitate collaboration, a group workspace is necessary in addition to personal learning devices.

Results of social interaction analysis

The group dynamic chart indicates that the shared visual focus of students differed between the 1:1 and Shared-Display environments. Students displayed a shared visual focus in more discussion threads in the Shared-Display setting than in the 1:1 setting, 60 in the former as opposed to only 25 in the latter. In addition, more students were included in the shared visual focus occurring in the Shared-Display setting than in the 1:1 setting. On average, each shared visual focus involved 2.46 students in the Shared-Display setting, compared with the significantly smaller average of 0.80 students in the 1:1 setting ($t=-7.323, p<.001$). This finding indicates that, in the Shared-Display setting, students were more likely to be engaged in common discussion topics than distracted from the discussion by individual work.

Students displayed more hand-pointing behaviors in the Shared-Display environment than in the 1:1 setting. Students exhibited a total of 54 hand-pointing behaviors in the Shared-Display setting, compared with just 8 in the 1:1 setting. The hand-pointing comparison indicates that students interacted with each other in the Shared-Display setting in a livelier manner than when using the 1:1 learning style. Analysis of the group dynamic chart also reveals that informed agreement was sometimes indicated by hand-pointing. Of the 77 occurrences of informed agreement, 18 instances were accomplished by means of hand-pointing behaviors. Hand-pointing behaviors and shared visual focus were co-present in a coherent manner. The establishment of shared visual focus was accompanied by the occurrence of hand-pointing behaviors. Figure 4 shows one example of the co-presence of non-verbal interaction and informed agreement. Five group members reached agreement (utterance 59–64) when they pointed at and watched the shared display during discussion. In contrast, students who watched the screens of handheld devices incited informed agreement in few other participants. Therefore, the Shared-Display setting facilitated the collaboration and discussion process by encouraging students to participate in socially promotive activities, rather than restricting their focus to their own computers.

Results of argument process analysis

An analysis of the conversations that occurred in the 1:1 and Shared-Display settings (Table 4) demonstrates that group members were involved in more question interactions in the 1:1 setting (44%) than in the Shared-Display setting (32%). By contrast, group members presented more positions and arguments (11% and 17% respectively) when utilizing a shared display than when limited to Tablet PCs (6% and 12% respectively). An examination of conversational records reveals that, when they encountered problems, students presented them as issues and called for all group members to contribute their opinions. Since the shared displays provided a shared information space, students' personal work could be rendered on them. Hence, students did not frequently ask for input from peers and proposed fewer issues and questions in the Shared-Display setting than in the 1:1 setting. Nevertheless, students proposed more arguments and positions in the Shared-Display setting than in the 1:1 environment. Analysis of the discussion threads in table 2 also demonstrates that the average depth of threads was 4.32 in the Shared-Display setting, exceeding that of the 1:1 setting (4.21). It may be concluded, therefore, that the shared display enabled group members to articulate their ideas. Furthermore, in conversation, students used indexical words (Table 5) more frequently in the Shared-Display setting (31 times) than in the 1:1 setting (7 times). Brown *et al.* (1989) defined indexical words as those that index or point clearly to a part of the situation in which communication is being conducted. This phenomenon, as it exists in this study, demonstrates that students can easily point out information by using indexical words.

Table 4. Statistics of conversational utterances

| | Group1 | | Group 2 | | Group 3 | | Total | |
|-------------------|----------|----------|----------|----------|----------|----------|----------|----------|
| | 1:1 | Shared | 1:1 | Shared | 1:1 | Shared | 1:1 | Shared |
| Issue/questions | 21 (58%) | 16 (48%) | 21 (42%) | 7 (22%) | 21 (38%) | 20 (29%) | 63 (44%) | 43 (32%) |
| Position | 1 (3%) | 4 (12%) | 4 (8%) | 6 (18%) | 4 (7%) | 5 (7%) | 9 (6%) | 15 (11%) |
| Argument | 4 (11%) | 2 (6%) | 6 (12%) | 10 (31%) | 7 (13%) | 11 (16%) | 17 (12%) | 23 (17%) |
| Group development | 10 (28%) | 11 (33%) | 19 (38%) | 9 (28%) | 24 (43%) | 33 (48%) | 53 (37%) | 53 (39%) |

Table 5. Occurrence of indexical words

| | One-to-one (1:1) | Shared-Display |
|-------------------|------------------|----------------|
| Issue/questions | 2 | 14 |
| Position | 0 | 8 |
| Argument | 0 | 6 |
| Group development | 5 | 3 |

Results of criteria elicitation analysis

Students produced a total of 25 question items. These items concern six different dimensions of the collaborative learning environment supported by 1:1 technologies. Table 6 summarizes the six dimensions and the criteria included in each, as adapted from the student-derived questionnaires. Of the 25 items on the students' questionnaire, five items relate to the four criteria in the dimension of discussion, seven items to the three criteria in the dimension of facilitation of group work, one item to the one criterion in the dimension of supporting activity awareness, two items to the two criteria in the dimension of individual work, two items to the two criteria in the dimension of general learning interface design, and seven items to the five criteria in the dimension of general HCI (Human Computer Interaction) design. From these criteria, one can infer that students feel that effective 1:1 learning environments must have both an adequate interface design to support individual work on individual devices and adequate functions to support efficient and effective collaborative work (i.e. discussion, group work, and activity awareness).

Table 6. Students' perception of the 1:1 and Shared-Display environments

| Dimension | Criteria | # of item | 1:1 ⁺ | Shared |
|-----------------------------------|---|-----------|------------------|--------|
| Discussion | Easy for discussion, shortens discussion time, increases discussion frequency, aids learning through discussion | 5 | 2.64 | 4.50** |
| Group work | Aids group work efficiency and generation of group answers, facilitates collaboration, facilitates group shared understanding | 7 | 2.65 | 4.29* |
| Activity awareness | Aids awareness of others' answers | 1 | 3.15 | 4.30** |
| Individual work | Aids editing of individual answers, aids learning through generation of individual answers | 3 | 3.61 | 4.00** |
| General learning interface design | Facilitates learning, increases motivation to learn | 2 | 3.12 | 4.30* |
| General HCI design | Easy to manipulate, user friendly, eases off usage load, robust, evokes willingness to use the system again, shortens learning time of system functions | 7 | 3.03 | 4.03** |

*p<0.05 **p<0.01

⁺ represents the average score of all the items in a dimension.

Judging by their proposed criteria, students perceive the Shared-Display setting as providing more substantial support than the 1:1 setting in the criteria of ease of discussion, increase in discussion frequency, learning through discussion, and shortening of discussion time. Their feedback was consistent with the findings of interaction thread

analysis in that the shared display encouraged more members to contribute to the discussion threads. Furthermore, students considered the shared display beneficial to group work in the criteria of aiding group work efficiency and generation of group answers, facilitating group shared understanding, and facilitating collaboration. Student feedback was consistent with the findings of the social interaction analysis, in that students were more likely, in the Shared-Display setting, to be engaged in common discussion topics than distracted from the discussion by individual work. Students perceived that the shared-display environment significantly promoted group awareness for the collaborative work. This might explain the significant increase in shared visual focus in the Shared-Display setting.

On the subject of general learning interface design, students regarded facilitating learning and increasing the motivation to learn as two important features of a learning environment. Students considered the Shared-Display setting to be satisfactory in relation to both criteria and regarded it as a favorable environment for learning. In the dimension of general HCI design, according to interview results, students regarded the facilitation of group discussion, rather than merely the presence of an easy-to-use interface, as an important factor in easy manipulation. They also thought that shared displays did not add extra usage load, but served to facilitate group discussion. Therefore, students preferred the Shared-Display setting with respect to the general HCI design dimension. Consistent with their opinions, students showed higher average scores in the Shared-Display setting.

Conclusion and implications

Capturing how students learn with peers through different technological devices and how these devices influence the interaction among students is a difficult task, because the representation of information and knowledge is distributed among different ubiquitous devices. This study captures both the conversation logs of groups and their social cues, which are often not examined by traditional online interaction analysis methodologies, as mediated by different technological devices (Liu & Tsai, 2006; Stahl, 2005). This integrated analytical methodology was found to be helpful for both quantitatively and qualitatively analyzing students' face-to-face discussions and collaborative problem solving activities.

Effectiveness of shared-display environment on participation and negotiation

The results of integrated analysis revealed that students in the 1:1 environment frequently exhibited fragmented communication patterns, i.e. most interactions occurred between two students. The shared displays attracted more students to participate in discussion threads than 1:1 environment. Furthermore, students showed informed agreements with more peers in shared-display environment than they did in 1:1 environment. Therefore, the shared display could not only facilitate students' participation but also negotiation process in the collaborative problem solving activity. These findings support that shared workspaces attracted students' participation and facilitated negotiation process in the scenarios of using handhelds to support collaborative problem solving activities.

Student questionnaire feedback reveals that shared displays could provide substantial support for improvement of awareness of group answers, ease of discussion, generation of group answers, facilitation of collaboration, efficiency of discussion, and willingness to use the system. The shared display helps students to integrate different ideas and to construct shared visual focus (attention). Therefore, learners in 1:1 classrooms need not only an individual learning space for gathering their learning resources and organizing their thoughts, but also a shared learning space to construct shared attention.

Effectiveness of shared-display environments on argument process

The integrated analysis reveals that students proposed more arguments and positions when collaborating in the Shared-Display environment than they did in the 1:1 environment. This finding indicates that the 1:1 learning environment needs not only individual workspaces, but also a shared workspace for students to contribute and explain their ideas. These findings are consistent with Greenberg's argument that a physical shared workspace is required to improve social interaction and collaboration (Greenberg, 1996). Due to the lack of shared workspace, students provided only with personal handheld devices are restricted to interacting with peers on their individual devices and thus cannot take part in lively promotive discussion. This study indicates the necessity for environmental

transformation in classroom layout and equipment in order to establish effective and socially promotive collaboration with personal learning devices.

Effectiveness of shared-display environments on social interaction

The results of integrated analysis demonstrate that students in the Shared-Display setting often explained their thoughts by hand-pointing. Moreover, students frequently established shared visual focus and informed agreement in the Shared-Display setting. However, students in the 1:1 setting rarely demonstrated hand-pointing behaviors or shared focus. Because hand gesture and eye contact behaviors are two indicators of social presence and mutual awareness, it is apparent that the shared display facilitated mutual awareness to augment social presence and socially promotive collaboration (Argyle & Dean, 1965; IJsselstein et al., 2000). Handheld devices may impede socially promotive interaction if the design of the devices and software is not conducive to the communication these same devices are used to mediate (Gunawardena, 1995; Richardson & Swan, 2003). Previous studies have confirmed that social presence is a key factor in effective and promotive computer-mediated learning activities (Garrison et al. 2000; Kim et al., 2006). Roth & Welzel (2001) also confirmed that gestures help students to construct complex learning activities. Students in the 1:1 setting tended to concentrate on using their own devices, disregarding the activities of the other participants, while students with access to a shared display were able to link complicated information and to exchange ideas on a shared workspace with the use of lively non-verbal cues. Thus, the shared display can encourage students to participate in socially promotive activities. It is our recommendation that 1:1 environments and activities should be designed to encourage all participants to participate jointly in shared socially promotive activity.

Student responses state that looking at the shared display increased their awareness of collaborative work. Activity awareness was achieved through the shared display rather than the handheld devices. This finding confirms the importance of activity awareness (Greenberg et al., 1996; Hill & Gutwin 2003; Liu et al., 2007) and of social clarity in face-to-face situations (Erickson & Kellogg, 2000). Students rarely established shared focus in the 1:1 setting, where information and activities were often concealed in individual devices. The lack of activity awareness impeded collaboration between group members. Students demonstrated more effective interactive behaviors and active engagement in the Shared-Display setting than in the 1:1 setting, because the shared display facilitated interaction by raising activity awareness. This finding confirms the requirement for visibility and awareness of activity processing in 1:1 learning environments.

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Reflections of Students in Their Use of Asynchronous Online Seminars

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ABSTRACT

This paper reports on research that has been carried out into the use, process, and effectiveness of an asynchronous online seminar within an undergraduate sports studies degree programme. Contemporary sources are used to justify the use of technology supported learning (TSL) in higher education and to inform a reflective and critical account of the planning and delivery of an asynchronous online seminar. Through student feedback gained from qualitative questionnaires, we conclude that the online seminar made a positive contribution to the learning experience of the majority of participating students. However, encouraging widespread participation was problematical. It was also clear that some participants only took part because of the extrinsic rewards on offer and that this might have had some impact on the quality of their learning experience (Biggs, 2003). Despite the benefits of the online seminar, we would also suggest that where student numbers are manageable, the benefits of a “blended” approach, delivering online seminars in conjunction with more traditional face-to-face seminars, should be considered.

Keywords

Forum, Engagement, Technology, Learning, Teaching, Collaboration

Introduction

Increasing student numbers in higher education make it much more difficult for university teachers to incorporate traditional face-to-face seminars within their teaching (Maier & Warren, 2000). Indeed, the difficulties in using strategies which depend on close contact with students have resulted in the asynchronous online seminar becoming more popular amongst university teachers (Biggs, 2003). This article focuses on the asynchronous online seminar and examines the extent to which such an activity can enhance the student learning experience.

Technology has the potential to enhance the learning of students if used appropriately. It can encourage more independent and active learning as well as be an efficient means of delivering course materials (McKimm, Jollie, & Cantillon, 2003). However the emphasis must be on sound pedagogical design rather than on the technology itself (Downing, 2001). This can be supported by an informed institutional policy and developmental infrastructure which enable staff and inform what is considered effective use of technology in learning and teaching (Moron-Garcia, 2006).

A key reason for the use of technology within a learning situation is to enhance the quality of learning and teaching. It should follow that this use demonstrates the characteristics of good learning and teaching practice. Research over the past 20 years has given some indications as to the characteristics of a quality learning and teaching experience. For example, Marton and Säljö (1997), Ramsden (1992), Biggs (2003), and Prosser and Trigwell (1999) have identified qualitatively different student approaches to learning that can be used to characterise the differing ways in which students engage with learning tasks and their learning environment. Research has shown that students' learning outcomes are correlated with these different approaches to their learning, and that a major influence upon how they perceive the nature of their learning is through the methodologies and tasks used by teaching staff (Kember, 1997). Social constructivist perspectives on the furtherance of learning (Wenger, 1998) advocate that encouraging collaboration and interaction with peers, and thus exposure to alternative perspectives through an opportunity to negotiate meanings, might be a beneficial method of fostering deep learning. The necessary processes of reflection, self-evaluation, and initiation of new learning (Kolb, 1984) are also likely to be triggered and emulated in such collaborative learning situations. Group work as a methodology in face-to-face situations may well promote a deep approach to learning. It has a well-established rationale (Biggs, 2003) and is the cornerstone of pedagogic approaches such as discussion forums.

A number of writers have outlined the numerous advantages of using the asynchronous online seminar within higher education teaching and have suggested ways in which this type of technology supported learning (TSL) might help to

improve the student learning experience. For example, Maier and Warren (2000) have argued that the online seminar can actually provide a better quality of discussion, when compared to a traditional face-to-face seminar. Williams (2002) concurred, suggesting that an asynchronous seminar enables students to consider and construct more thoughtful comments before sharing them with the class. Littlejohn and Stefani (1999) have suggested that the permanence of electronic contributions can also be considered beneficial because they can provide students with a resource which can be used for revision or to enhance future learning. The suggestion that an online discussion equalizes the opportunity to contribute is also of note (Maier and Warren, 2000). Many students like to think before they speak or may speak English as a second language, while others may be quiet, shy, and easily “talked over” (Williams, 2002, p. 266). In a face-to-face seminar, these individuals may be disadvantaged but would be more able to contribute in an online debate (Maier & Warren, 2000). Similarly, during an online discussion, contributions are less likely to be judged as a result of race, gender, or disability (Maier & Warren, 2000), and so the learning experience of a wider range of students can be enhanced.

In providing a critical examination of the asynchronous online seminar, we also need to acknowledge potential drawbacks. For example, some students could actually be intimidated by the permanence of contributions when compared to easily forgotten face-to-face comments (Williams, 2002), while students without frequent access to a computer will be disadvantaged (Inglis, Ling, & Joosten, 1999). Online discussion also takes place without the rich mixture of speech and body language that can help to convey meaning and emotion, and so students do not get the opportunity to practise the art of verbal communication. Finally, it is notoriously difficult to encourage participation in an optional online activity (Kear, 2004; Mason, 1999), and so Salmon (2003) stressed the importance of actually motivating students to take part.

This paper is a consideration of the effectiveness of a particular TSL solution within a specific module that is delivered as part of the undergraduate sports studies degree programme at a post-1992 British university. The evaluation is based on the feedback of students who participated in the online seminar and aimed to discover the extent to which this type of TSL can enhance the student learning experience and emphasise any improvements that should be made in any future delivery.

Design of the investigation

Context

The context of this piece of research was set in a second-year undergraduate sports sociology module. During week one of this module, a traditional face-to-face seminar activity was undertaken within the classroom session in order to help the students to arrive at a suitable issue that could form the basis of a presentation that was a requirement of the module. As a result of the discussion which occurred within this seminar, each student was able to produce an outline of a presentation that they could conceivably deliver later in the module. This outline included the issue that they would present on (e.g., the sport of boxing), the potential title (e.g., should boxing be banned?), the different arguments that could be presented within the presentation, and the way in which they could apply various social theories to their particular issue.

In previous years, the students presented this outline at a tutorial in week two, when the module staff would provide feedback on their proposal. On this occasion, the students were given a further opportunity to develop their presentation via the use of an asynchronous online seminar. Tutorials were then arranged in week three so that module staff could consider the students’ presentation proposals. Within the asynchronous online seminar students were expected to upload their presentation proposals into a forum on the university’s online learning framework before giving feedback to three of their peers. This feedback needed to emphasise the strengths of each of the presentation proposals they considered but also needed to highlight at least two areas where they felt the presentation proposals could be improved.

Delivery of the asynchronous online seminar

The online seminar was structured in a way that would enhance the student learning experience and give the students a better chance of producing a quality presentation assessment. Indeed, we have taken some time in this section of the article to show how the delivery of this TSL reflected the thinking of a number of learning theories. First, we

were conscious that students learn in a variety of different ways and we were keen for the online seminar to reflect these differences. For example, by providing feedback on the work of their peers, the students were, in essence, taking on the role of the teacher. This was considered a strength of the TSL, as Glasser (cited by Biggs, 2003) as well as McKeachie, Pintrich, Lin, and Smith (1987) have emphasised that student learning will be enhanced when students teach other students. The TSL was also mapped against Bloom's taxonomy (1956). Maier and Warren (2000) explained that this taxonomy could be divided into three overlapping domains, namely, the cognitive, affective, and psychomotor domains. Most learning outcomes within higher education come from the cognitive domain, which is separated further into knowledge, comprehension, application, analysis, synthesis, and evaluation. The TSL was structured in a way that would encourage the students to move beyond the initial stages of this cognitive domain and, by asking them to consider the work of their peers and provide some kind of feedback, we hoped that some of them might actually be able to analyse or even evaluate the proposals presented by their fellow learners. This was facilitated by the tutor, who posted within the forum that feedback was required. The students found the prompt and the opportunity to provide feedback a satisfying and rewarding experience.

There were, however, other factors which needed to be considered. For example, it was clear that if the student learning experience was to be enhanced in this way, students needed to actually take part. Consequently, steps were taken to motivate the students to participate (Salmon, 2003). There were a number of ways in which the delivery of the online seminar was shaped by the need to do this. First, students were informed that if they fully participated in the online seminar they would have some input to the scheduling of their presentations later in the module, enabling them to avoid weeks when they had to submit assessment in other modules, that is, scheduling or phasing work during the course rather than submitting it at the end of the module. Second, the level at which the task was set was related to research by Marton and Saljo (cited by Biggs 2003, p. 11), which split student methods of learning into two. The surface approach is where a learner skims through, allowing facts to be absorbed but not the overall point the author is making. So here we are exposing students to new knowledge for assimilation, not necessarily for understanding. In the deep approach, the learner delves below the surface to understand the meaning. Biggs's definition of good teaching (2003, p. 13) is one in which the deep approach is encouraged, and to maximise the chances of this happening, he suggested a theory of constructive alignment (2003, p.32), where levels of understanding are defined which become the activities that students perform. Whilst we were hoping that a deeper approach to learning would be facilitated, we were clear that the process had to be constructively aligned.

Salmon (2003) explained that e-moderators cannot be complacent about students' online skills and should provide activity that allows all students to participate. Many students are likely to be driven by achievement motivation and are more likely to participate in tasks that they know they can complete (McClelland, 1985). By providing an activity that was based around a discussion forum, the task was kept at a simplistic level, making widespread participation more likely. Nevertheless, the need to avoid complacency about a student's online skills (Salmon, 2003) meant that some training was given during the contact session in which the task was issued.

A further area to consider is whether or not the students actually feel that the activity is of value (Salmon, 2003). Expectancy-value theory (Feather, 1982; Biggs, 2003) suggests that learning activity must have some perceived value to the learner in order to encourage participation. It was consideration of this theory that encouraged us to link the TSL to the presentation assessment that the students would eventually complete in this module. Indeed, a number of authors (Maier & Warren, 2000; Salmon, 2003) have argued that because all but the most experienced e-learners are likely to be extrinsically motivated, participation in online learning will often increase if that activity is linked to assessment.

It should also be noted that any interaction within the seminar was between the students, with tutor input kept to a minimum. Kear (2004) found that students using these types of seminars attached a greater level of importance to the input of fellow students than they did to the contributions of staff, while others have also suggested that students place great value on the advice and support that they get from their peers (Maier & Warren, 2000; Singletary & Anderson, 1995). It was hoped that the students would be more likely to participate in the online seminar if this type of student interaction was encouraged. (O'Donoghue & Singh, 2001).

Additional factors included access. For example, delivering the seminar through the university's online learning framework meant that all students could access the seminar via their own university online account either at home or on a university machine, which addresses the issue of universal access (Inglis et al., 1999) and the need for an activity that equalizes opportunity to contribute (Maier and Warren, 2000). Finally, online seminars will not provide

any opportunity to practice the art of verbal communication, and so Maier and Warren (2000) suggested that it is a good idea to retain some face-to-face seminars. This is why this TSL was actually used to supplement the more traditional classroom-based face-to-face seminar that was delivered in week one of the module.

Evaluating the asynchronous online seminar

Student feedback provides one of the most satisfactory methods of evaluating the effectiveness of teaching methods (Biggs, 2003). Kear (2004) used a student feedback survey to evaluate an online course at the Open University, while MacDonald and Thompson (2005) used similar techniques as part of their evaluation of an online programme of study, and we have also used student feedback to evaluate the effectiveness of this asynchronous online seminar. In the contact session that followed the student's participation in this TSL, 29 participants completed questionnaires that aimed to gauge the effectiveness of the asynchronous online seminar in helping them to produce a proposal for the presentation element of the module in question. Of these, some 75 percent also participated in the peer evaluation process. The questionnaire used a qualitative approach that is often encouraged when gaining student feedback because it is more able to elicit student reactions than single-response quantitative-style questions (Stringer & Finlay, 1993). All questionnaires were completed anonymously within the contact session. The responses were analysed by the course team in conjunction with various learning theories in order to gauge the value and effectiveness of the online seminar in enhancing the student learning experience. The evaluation focused on understanding the content of the seminars, application of learnt knowledge, and transference into other domains of understanding. In summary, did the activity promote a deeper sense of learning?

Discussion of results

This analysis has helped to identify the effectiveness of the chosen TSL and has helped us to provide recommended future actions in the delivery of similar online activity. Initial feedback suggests that the majority of students received this online seminar in a positive manner ($n = 27$), and it was clear that a number of students attached some value to the task because of the assistance that they gained with regard to their presentation assessment:

- [I received] different peoples ideas and different ideas to incorporate into my assignment (Student 29).
- [I got] inspiration from other presentation topics (Student 10).
- It did help as it gave me a small idea of how the presentation will be received and how it could be improved (Student 14).

A number of authors (Maier & Warren, 2000; Salmon, 2003) have argued that student motivation will often increase if the activity is linked to assessment, and this feedback would certainly substantiate these claims. Furthermore, this data would also concur with the expectancy-value theory (Feather, 1982; Biggs, 2003), which suggests that an activity must have some value to the students in order to encourage motivation and subsequent participation. Nevertheless, some caution should be exercised at this point, as it was clear that certain students ($n = 5$) were still not motivated to participate despite the fact that the online seminar was linked to assessment:

- I did not have the time; I had other work to do (Student 16).
- We had already decided on a presentation topic in class (Student 28).
- I partly forgot, but also I don't have any free time on Monday–Wednesday so I didn't get the task done while it was still fresh in my mind (Student 7).

Moreover, the fact that not all students who participated had implications with regard to the student learning experience because not all participants actually received feedback for their presentation proposal:

- Personally the classroom seminar was more useful as we did not receive any feedback [online] (Student 4).
- No feedback was received online (Student 23).
- I cannot say [how useful it would have been] as I haven't received any feedback. It would have been useful though (Student 6).

It could be argued that to encourage full participation, an online task should not just be linked to assessment (Maier & Warren, 2000; Salmon, 2003) but should be assessed, and the fact that a number of students failed to participate in this activity might provide some support for this argument. However, there are those who might feel somewhat uncomfortable with this particular recommendation, and a brief consideration of motivation theory might help us to

understand why this is the case. Motivation theory suggests that it is the intrinsically motivated individuals who will put more into, and get more out of, any task that they perform. Intrinsically motivated students gain intellectual pleasure from problem solving and have an inherent spark that causes them to question, wonder, and hypothesise. It is this approach that drives deep learning and the best academic work (Biggs, 2003).

Extrinsically motivated individuals do not focus on the process of learning, or even the product, but on the consequence of the product, such as obtaining the reward that a pass mark would bring if, as suggested above, an online task were assessed (Biggs, 2003). Biggs argued that extrinsically motivated learners tend to adopt a surface approach to learning and so we could certainly question the value of motivating students to participate in an online task by offering an extrinsic reward. Taking these ideas into account, we were concerned, although not surprised (Salmon, 2003), that several students who participated in this online seminar seemed to be extrinsically motivated. As detailed earlier, students fully participating in this particular online task were given some input into the scheduling of their presentation. Certain participants suggested that this was the only reason that they participated in the seminar and gave little indication that the seminar had helped their learning:

- We get to choose when or at least have an input into our presentation time (Student 9).
- [We] can choose when our presentation will be (Student 4).

Although these attempts to encourage student participation were done so that students would benefit from the online learning experience, we started to ask ourselves how beneficial this had actually been. We can clearly identify concerns about the extrinsic motivation of the students who only completed the task because of the extrinsic benefits on offer and ask ourselves about the quality of their learning experience (Biggs, 2003). Indeed, we might recommend that, in order to improve the student learning experience, we develop future online activities that have an intrinsic interest to the students (Print, 1993). However, it might be unfair to suggest that when considering intrinsic and extrinsic motivation in this way, we should consider online learning any different from other types of learning.

One of the perceived strengths of this online seminar was that it enabled students to give and receive feedback for their presentation proposals. There were two reasons why the seminar was delivered in this way. Firstly, students place a great deal of value on the views and opinions of their peers (Singletary & Anderson, 1995; Kear, 2004; Maier & Warren, 2000) and this idea gained support in the student feedback with a number of participants ($n = 24$) suggesting that the main benefit of the online seminar was the feedback that they received from their classmates:

- The online seminar was of most value as the feedback that you could receive was most helpful. (Student 11).
- The feedback from other/fellow students. (Student 14).
- Seeing people's views on our work and looking at other people's ideas. (Student 27).
- Getting feedback from others and receiving new ideas (Student 2).

The second reason for structuring the TSL in this way was that it enabled the students to actually give feedback, meaning that they were, in essence, taking the role of the teacher. This should have been an especially useful aspect of the seminar because learning tends to be enhanced if students teach other students (Glasser, 1988, cited by Biggs, 2003; McKeachie et al., 1987). Additionally, we hoped that students might learn to analyse and evaluate their peers' work and reach the higher levels of Bloom's taxonomy (Maier & Warren, 2000). However, the students were less aware of the benefits of actually providing feedback, with only one student commenting on this:

- I don't know because nobody replied, but the feedback that I gave made me think about different issues (Student 1).

Finally, it has been useful to consider student perceptions of the online seminar in comparison to the classroom seminar. The responses in this area were varied, with certain students attaching more value to the online seminar:

- The online seminar was of most value as the feedback you could receive was helpful (Student 11).
- The online seminar was the most helpful (Student 24).
- [The online seminar] was most useful because of the feedback that we got from the other students (Student 8).

Conversely, other students seemed to gain more from the classroom seminar:

- I feel that talking to people in class is more beneficial than online (Student 3).
- The classroom discussions I feel were very helpful and very encouraging (Student 26).
- The classroom seminar was of the most help to me (Student 5).

This feedback perhaps endorses the decision to run this online seminar in conjunction with a more traditional face-to-face seminar. Indeed, we should not dismiss the usefulness of the classroom seminar too easily (Maier & Warren, 2000), and this particular student feedback would help to support any recommendation that future online seminars should, where student numbers allow, supplement a classroom-based discussion. However, with regard to this particular online seminar, we might consider that it was implemented in a module of 30 students and that one of the major benefits of an online seminar is that it enables teachers to manage larger numbers of students more effectively (Maier & Warren, 2000). Indeed, Biggs (2003) discussed the management of large classes and the problems associated with using strategies that depend on close contact with a large number of students. Therefore, while we would recommend that online and classroom seminars supplement each other in the case of smaller classes, we may have to exercise some caution if using this approach when teaching larger groups of students.

Conclusions

The use of an asynchronous online seminar seemed to enhance the learning experience of the students. Further work needs to be undertaken to qualify and quantify this, as we would hope that the use of TSL has engendered a measurable and deeper approach to learning. Several students valued the feedback they received ($n = 22$) and suggested that it helped them to provide a clearer presentation proposal. However, there are certain issues that need to be considered when delivering similar activities in the future. For example, considering the potential benefits in this area, it was a concern that the students did not acknowledge the usefulness of actually giving feedback to their peers. This would need to be emphasised in more detail in the future.

There was also an issue with participation, and a tenuous recommendation suggested that contributions could be formally assessed in order to encourage a greater level of engagement with the TSL. However, caution must be expressed in this area because students motivated by such extrinsic rewards tend to adopt a surface approach to learning, and so the benefits of motivating students in this way would appear to be questionable. Indeed, it was a concern that a number of students who completed this particular TSL did so only because of the extrinsic rewards available, and so we suggest that teachers channel their energies into providing an online activity that has an intrinsic value to students and move away from encouraging participation through extrinsic rewards.

Finally, student feedback that praised the contribution of the classroom seminar suggested that it might be unwise to consider replacing the traditional face-to-face seminar with online discussion. Consequently, it is recommended that, where student numbers allow, future online seminars be used to supplement more traditional face-to-face activity. However, in making such a recommendation we need to acknowledge that this particular TSL was delivered to a class of 30 students and that a benefit of the online seminar is that teachers can manage large classes more easily. Indeed, the difficulties in running classroom seminars with large groups of students would need to be taken into account when considering this recommendation. Allowing students to feel involved and to take responsibility for their own learning (Davies & Smith, 2006) will foster a deeper understanding of concepts and knowledge, and their application. The technology does not have to be complex or leading edge. It does, however, need to be constructively aligned with the curriculum objectives and learning outcomes so that the students can become actively engaged in their learning and the learning and teaching process, rather than be passive recipients of knowledge and information.

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An Analysis of the Technology Acceptance Model in Understanding University Students' Behavioral Intention to Use e-Learning

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ABSTRACT

Many universities implement e-learning for various reasons. It is obvious that the number of e-learning opportunities provided by higher educational institutes continues to grow in Korea. Yet little research has been done to verify the process of how university students adopt and use e-learning. A sample of 628 university students took part in the research. The structural equation modeling (SEM) technique was employed with the LISREL program to explain the adoption process. The general structural model, which included e-learning self-efficacy, subjective norm, system accessibility, perceived usefulness, perceived ease of use, attitude, and behavioral intention to use e-learning, was developed based on the technology acceptance model (TAM). The result proved TAM to be a good theoretical tool to understand users' acceptance of e-learning. E-learning self-efficacy was the most important construct, followed by subjective norm in explicating the causal process in the model.

Keywords

e-Learning, Technology acceptance model, Structural equation modeling, Self-efficacy

Introduction

A recent trend in higher education has been to set up e-learning systems that provide students with online access and learning content. What drives this trend are changes in students' demographic factors, in educational delivery market conditions, and in innovation technology itself (Concannon, Flynn, & Campbell, 2005). There are, however, numerous barriers to the integration of instructional technology into higher education, such as technology infrastructure, faculty effort, technology satisfaction, and graduates competency (Surry, Ensminger, & Haab, 2005). Even many higher online educational institutions have failed due to the high cost of technology, poor decisions, competition, and the absence of a business strategy (Elloumi, 2004). Many universities that provide e-learning face enormous difficulty in achieving successful strategies, including the delivery, effectiveness, and acceptance of the courses (Saadé, 2003). Merely offering any conceivable course and attempting to replicate classroom experience online cannot meet the students' needs and may cause unexpected failure (Kilmurray, 2003). University students' persistent frustration in web-based education is another problem in terms of online learning. This drives more student-centered research of online education (Hara, 2000). With the growing reliance on information systems and increasing rapidity of the introduction of new technologies into learning environment, identifying the critical factors related to user acceptance of technology continues to be an important issue (Yi & Hwang, 2003).

Korea takes full advantage of ICT in supporting all levels of education and human-resource development, and e-learning is considered one of the important alternatives for current knowledge-based society (Kim & Santiago, 2005). Korea's e-learning readiness was ranked fifth in the world based on a report of the Economist Intelligence Unit (2003). Most universities have continued to offer partial, blended, or fully online e-learning courses since the late 1990s. At present, most off-line universities have either introduced an e-learning plan or have implemented e-learning. Despite quantitative growth of e-learning, there is growing concern that stresses quality assessment for e-learning in higher education in Korea (Lee, 2006). In addition, barriers in terms of e-learning utilization in universities or colleges still exist (Leem & Lim, 2007).

Consequently, developers and deliverers of e-learning need more understanding of how students perceive and react to elements of e-learning along with how to most effectively apply an e-learning approach to enhance learning (Koohang & Durante, 2003). In addition, knowing students' intentions and understanding the factors that influence students' beliefs about e-learning can help academic administrators and managers to create mechanisms for attracting more students to adopt this learning environment (Grandon, Alshare, & Kwan, 2005). Therefore, it is necessary to conduct research that deals more intensively with learners' perception of, attitude towards, and intention to use e-learning. However, little research has been done in Korea to empirically determine the relationship of university students' e-learning use with personal factors such as perceived usefulness, easiness, attitude, intention to use, and self-efficacy, with social factors such as subjective norm and organizational factors such as system accessibility.

Objectives

This study proposed an integrated theoretical framework of university students' e-learning acceptance and intention to use based mainly on the technology acceptance model (TAM). The objectives of the study were to analyze the relationship of university students' intention to use e-learning with selected constructs such as their attitude, perceived usefulness, perceived ease of use, self-efficacy of e-learning, subjective norm and system accessibility, and to develop a general linear structural model of e-learning acceptance of university students that would provide a school manager or an educator with implications for better implementing e-learning. Also determined were some descriptive characteristics of e-learning use and those selected constructs.

Research hypotheses

In accordance with the previously stated objectives and consistent with related literature, this study tested the following hypotheses:

- H₁: University students' behavioral intention to use e-learning is affected by their attitude (H₁₁), perceived usefulness (H₁₂), perceived easy of use (H₁₃), e-learning self-efficacy (H₁₄), subjective norm (H₁₅), and system accessibility (H₁₆).
- H₂: University students' e-learning attitude is affected by their perceived usefulness (H₂₁), perceived ease of use (H₂₂), e-learning self-efficacy (H₂₃), subjective norm (H₂₄), and system accessibility (H₂₅).
- H₃: University students' perceived usefulness of e-learning is affected by their perceived ease of use (H₃₁), e-learning self-efficacy (H₃₂), subjective norm (H₃₃), and system accessibility (H₃₄).
- H₄: University students' perceived ease of use of e-learning is affected by their e-learning self-efficacy (H₄₁), subjective norm (H₄₂), and system accessibility (H₄₃).

Literature review and theoretical framework

One of the well-known models related to technology acceptance and use is the technology acceptance model (TAM), originally proposed by Davis in 1986. TAM has proven to be a theoretical model in helping to explain and predict user behavior of information technology (Legris, Ingham, & Collette, 2003). TAM is considered an influential extension of theory of reasoned action (TRA), according to Ajzen and Fishbein (1980). Davis (1989) and Davis, Bagozzi, and Warshaw (1989) proposed TAM to explain why a user accepts or rejects information technology by adapting TRA. TAM provides a basis with which one traces how external variables influence belief, attitude, and intention to use. Two cognitive beliefs are posited by TAM: perceived usefulness and perceived ease of use. According to TAM, one's actual use of a technology system is influenced directly or indirectly by the user's behavioral intentions, attitude, perceived usefulness of the system, and perceived ease of the system. TAM also proposes that external factors affect intention and actual use through mediated effects on perceived usefulness and perceived ease of use. Figure 1 depicts the original TAM (Davis, 1989).

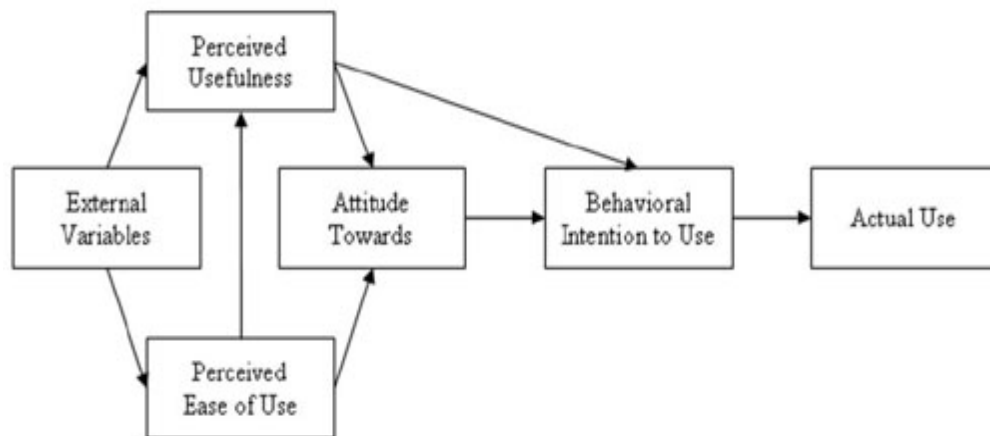


Figure 1. Original technology acceptance model (TAM)

TAM appears to be able to account for 40 percent to 50 percent of user acceptance. TAM has evolved over time. TAM2 extended the original model to explain perceived usefulness and usage intentions including social influence (subjective norm, voluntariness, and image), cognitive instrumental processes (job relevance, output quality, and result demonstrability) and experience. The new model was tested in both voluntary and mandatory settings. The results strongly supported TAM2 and explained 60 percent of user adoption using this updated version of TAM (Venkatesh & Davis, 2000). This study adopted TAM2 as the baseline model in addition to TAM.

Several studies have examined TAM as a model to explain how people adopt and use e-learning. Selim (2003) stated that there was a need to investigate TAM with web-based learning. He put forward the course website acceptance model (CWAM) and tested the relationships among perceived usefulness, perceived ease of use and intention to use with university students using the structural equation modeling techniques of the LISREL program. He concluded that the model fit the collected data and that the usefulness and ease of use turned out to be good determinants of the acceptance and use of a course website as an effective and efficient learning technology. Perceived usefulness can be defined as the extent to which a university student believes using e-learning will boost his or her learning. Meanwhile perceived ease of use is defined as the extent to which one believes using e-learning will be free of cognitive effort. In this study, e-learning refers to pure, web-based, asynchronous learning through an Internet site operated by the university. It is also supported by the learning management system (LMS) of the university

Lee, Cheung, & Chen (2005) did similar research with the LISREL program to investigate university students' adoption behavior towards an Internet-based learning medium (ILM) introducing TAM, but they integrated TAM with motivational theory. They included perceived enjoyment as an intrinsic motivator in addition to perceived usefulness and perceived ease of use into the TAM. According to their results, perceived usefulness and perceived enjoyment had an impact on both students' attitude toward and intention to use ILM. However, perceived ease of use was found to be unrelated to attitude. Meanwhile, Liu, Liao, and Peng (2005) integrated TAM with flow theory that emphasizes concentration on the structural model. They argued that university e-learning system users should be regarded as both system users and learners. In addition, Liu, Liao, and Peng adopted e-learning presentation type as an external variable into the model. They concluded that e-learning presentation type and users' intention to use e-learning were related to one another, and concentration and perceived usefulness were considered intermediate variables. Pituch and Lee (2006) added system and learner characteristics as external variables that were hypothesized to impact perceived usefulness, perceived ease of use, and use of an e-learning system. After conducting a structural equation modeling technique with LISREL, they concluded that system characteristics were important determinants to perceived usefulness, perceived ease of use, and use of an e-learning system, and that the theoretical model based on TAM was well supported. Saadé, Nebebe, and Tan (2007) also insisted that university students' participation and involvement were important to successful e-learning systems and therefore students' acceptance behavior should be assessed. They suggested that TAM was a solid theoretical model where its validity can extend to the multimedia and e-learning context.

Venkatesh and Davis (1996) focused on understanding the antecedents of the perceived ease of use. They concluded that computer self-efficacy acts as a determinant of perceived ease of use both before and after hands-on use and that the objective usability was found to be a determinant of ease of use only after direct experience with a system. In the meantime, Grandon, Alshare, and Kwan (2005) insisted that e-learning self-efficacy was found to have indirect effect on students' intentions through perceived ease of use. In addition, Mungania and Reio (2005) found a significant relationship between dispositional barriers and e-learning self-efficacy. They argued that educational practitioners should take into consideration the learners' dispositions and find ways through which e-learning self-efficacy could be improved. In this study, e-learning self-efficacy is generally represented as the personal confidence in finding information and communicating with an instructor within the e-learning system and the necessary skills for using the system.

As suggested in TAM2, subjective norm, one of the social influence variables, refers to the perceived social pressure to perform or not to perform the behavior (Ajzen, 1991). It seems important to determine how social influences affect the commitment of the user toward use of the information system for understanding, explaining, and predicting system usage and acceptance behavior (Malhotra & Galletta, 1999). According to the study done by Grandon, Alshare, and Kwan (2005), subjective norm was found to be a significant factor in affecting university students' intention to use e-learning. In contrast, the study done by Ndubisi (2006) showed that subjective norm had no significant effect on university students' intention to use e-learning. This kind of inconsistency may be resolved

through the structural equation modeling (SEM), which indicates spurious effects and indirect effects as well as direct effects (Sobel, 1987).

In general, variables related to the behavioral intention to use information technology or to the actual use of information technology could be grouped into four categories: individual context, system context, social context, and organizational context. While social context means social influence on personal acceptance of information technology use, organizational context emphasizes any organization's influence or support on one's information technology use. Thong, Hong, and Tam (2002) identified relevance, system visibility, and system accessibility as organizational context variables. They reported that the organizational context affects both perceived usefulness and perceived ease of use of a digital library. Lin and Lu (2000) similarly reported that higher information accessibility brings about higher use of information and higher perception of ease of use. In this study, e-learning accessibility refers to the degree of ease with which a university student can access and use a campus e-learning system as an organizational factor.

Research design

Based on the previous research, a theoretical model was developed. Figure 2 represents a theoretically interesting model to be tested and analyzed. The arrows linking constructs (latent variables) specify hypothesized causal relationships in the direction of arrows. The arrows between constructs and indicators (observed variables) symbolize measurement validity. Perceived ease of use and perceived usefulness can be considered cognitive constructs. Attitude might be considered an affective construct. Meanwhile, intention to use could be regarded as a behavioral construct. In the model, x represents observed exogenous indicators and y represents observed endogenous indicators. To make the model simple to comply with space constraints, error terms for all observed indicators are excluded from the figure.

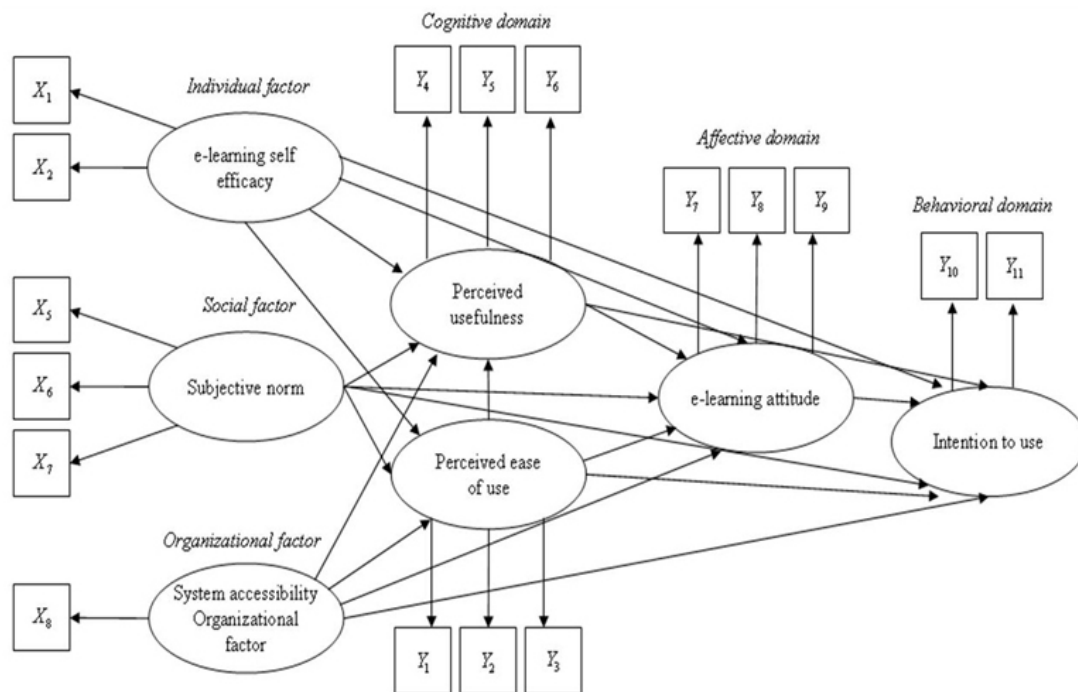


Figure 2. Theoretically interesting model

Method

Sample and procedure

The population in the study consist of university students at Konkuk University's Seoul Campus. There were 13,906 undergraduate students at the Seoul Campus. Among them 6,953 students took at least one e-learning course in the

spring semester of 2007. Normally, a sample size of 200 subjects would be an appropriate minimum, if one wanted to use LISREL (Marsh, Balla, & MacDonald, 1988). Similarly, Newcomb (1992) insisted that no one should use LISREL with fewer than 100 subjects. Considering those statements and the number of parameter estimates, the number of sample subjects was set at 650, about 9 percent of the 6,953 students who were taking e-learning courses.

After deciding the number of sample subjects, the researcher adopted a cluster sampling method to choose e-learning courses. Twelve e-learning courses were randomly selected from the 39 e-learning courses offered by the university. Six hundred fifty questionnaires were distributed to the students with the aid of professors in charge of each e-learning course during the mid-term exam period and collected immediately after the mid-term exam because some courses did not have a final exam. Six hundred twenty-eight students from the selected e-learning courses voluntarily participated in the study. All written exams were executed at the assigned times and places in the campus to prevent cheating, even though all learning activities took place completely online. Table 1 presents the demographic profile of the sample.

Table 1. Demographic information of the sample

| Variables | Number (N) | Percent (%) |
|--|------------|---------------|
| School year | | |
| Freshman | 73 | 11.62 |
| Sophomore | 194 | 30.89 |
| Junior | 135 | 21.50 |
| Senior | 226 | 35.99 |
| Gender | | |
| Male | 416 | 66.24 |
| Female | 212 | 33.76 |
| Number of e-learning courses taken this semester | | |
| 1 | 379 | 60.35 |
| 2 | 181 | 28.82 |
| 3 | 55 | 8.76 |
| 4 or more | 13 | 2.07 |
| Number of e-learning courses taken previously | | |
| None | 221 | 35.19 |
| 1 | 105 | 16.72 |
| 2 | 125 | 19.90 |
| 3 | 76 | 12.10 |
| 4 | 47 | 7.48 |
| 5 or more | 54 | 8.60 |
| Availability of high-speed Internet at home | | |
| Yes | 594 | 94.59 |
| No | 34 | 5.41 |
| Total | 628 | 100.00 |

Instrumentation

The instrument was developed by the researcher based on the objectives of the study and previous literature review. Content validity was established by pilot testing the instrument with 25 people: two e-learning administrative staff members, three graduate students in the Department of Educational Technology, and 20 students in Konkuk University. The completed instrument consisted of four parts. Part I was designed to identify demographic attributes of the respondents. It contained demographic items such as academic years, gender, the number of e-learning courses currently being taken, the number of e-learning courses previously taken, e-learning experience from other educational institutes, and the availability of high-speed Internet at home.

The questions in Part II were not only made based on Davis's prior studies with modifications to fit the specific context of the e-learning but also mainly adapted from the three studies for the objectives of the study: Lee, Cheung, & Chen, (2005); Ndubisi (2006); and Malhotra & Galletta (1999). Part II consisted of four sub-sections, as follows: perceived ease of use (PE), perceived usefulness (PU), attitude (AT), and behavioral intention (BI). The questions in Part III were developed by the researcher to measure e-learning self-efficacy (SE). It was measured by two indicators: confidence in finding information in the e-learning system and degree of necessary skills for using an e-learning system. The questions in Part IV were divided into two sections: subjective norms (SN) and system accessibility (SA). Subjective norms as social influence factors were measured mainly by adapting the scales done by Malhotra and Galletta (1999). Since most students have computers with Internet at home, system accessibility as an organizational factor was measured by only one indicator in the study, which was the difficulty in accessing and using e-learning systems in the university. All constructs were measured on seven-point Likert-type scales, from 1 = strongly disagree to 7 = strongly agree.

Statistical procedure

Data collected by the questionnaire were coded by research assistants. The data were recorded first in an MS Excel program and later transferred to Statistical Analysis System (SAS), Windows version 9.3. A random sample of five percent of the entered data was checked for coding accuracy. Descriptive statistical analyses such as mean, standard deviation, frequency, percent, and correlation were implemented using SAS. In order to test the hypotheses by structural equation modeling (SEM), LISREL Windows version 8.3 was employed.

Result

Analysis of measurement model

In the measurement model, both convergent and discriminant validity were checked. Convergent validity implies the extent to which the indicators of a factor that are theoretically related should correlate highly. All factor loadings (λ_x and λ_y) exceeded .70, which accounts for 50 percent of variance. Considering the sample size of the study, these scores are significant at a .05 significance level and a power level of 80 percent (Hair, Anderson, Tatham, & Black, 1998). Discriminant validity was confirmed by examining correlations among the constructs. As a rule of thumb, a .85 correlation or larger indicates poor discriminant validity in structural equation modeling (David, 1998). None of the correlations presents above .85. The result suggests an adequate discriminant validity of the measurement. The correlation matrix between constructs is shown in Appendix A. The correlation matrix between observed indicators is shown in Appendix B.

Two reliability tests were carried out to secure accuracy and consistency. Composite reliability (α) was obtained for each construct. Another measure of reliability calculated was the variance extracted measure (ρ). In general, a commonly used threshold value for acceptable composite reliability is .70. Meanwhile, guidelines recommend that the variance extracted value should exceed .50 for a construct. All measures fulfill the suggested levels with composite reliability ranges from .76 to .94 and variance extracted value ranges from .63 to .82. Table 2 shows the result of a confirmatory factor analysis and reliability test with some descriptive statistics, mean, and standard deviation. Figure 3 also describes graphically the relationships between constructs and observed indicators, presenting loadings and residuals.

Table 2. Summary of means, standard deviations, construct loadings, and reliabilities

| Construct | Measurement instrument | Mean (STD) | Loading | α/ρ |
|----------------------------|--|----------------|---------|---------------|
| Perceived ease of use (PE) | I find e-learning system easy to use (E_1). | 5.36 (1.16) | .84 | .93/.82 |
| | Learning how to use an e-learning system is easy for me (E_2). | 5.62 (1.18) | .95 | |
| | It is easy to become skillful at using an e-learning system (E_3). | 5.65 (1.16) | .92 | |

| | | | | |
|-------------------------------|---|----------------|-----|---------|
| Perceived usefulness (PU) | E-learning would improve my learning performance (U ₁). | 4.27 (1.29) | .91 | |
| | E-learning would increase academic productivity (U ₂). | 4.30 (1.31) | .93 | .88/.74 |
| | E-learning could make it easier to study course content (U ₃) | 4.20 (1.39) | .72 | |
| Attitude (AT) | Studying through e-learning is a good idea (A ₁). | 4.69 (1.43) | .95 | |
| | Studying through e-learning is a wise idea (A ₂). | 4.51 (1.41) | .93 | .94/.84 |
| | I am positive toward e-learning (A ₃). | 4.16 (1.39) | .86 | |
| Behavioral intention (BI) | I intend to check announcements from e-learning systems frequently (B ₁). | 4.88 (1.07) | .74 | .79/.66 |
| | I intend to be a heavy user of e-learning system (B ₂). | 4.52 (1.22) | .88 | |
| e-learning self-efficacy (SE) | I feel confident finding information in the e-learning system (S ₁). | 4.57 (1.16) | .85 | .76/.63 |
| | I have the necessary skills for using an e-learning system (S ₂). | 4.92 (1.23) | .73 | |
| Subjective norm (SN) | What e-learning stands for is important for me as a university student (N ₁). | 4.07 (1.27) | .84 | |
| | I like using e-learning based on the similarity of my values and society values underlying its use (N ₂). | 3.85 (1.37) | .86 | .89/.73 |
| | In order for me to prepare for future job, it is necessary to take e-learning courses (N ₃). | 4.02 (1.41) | .84 | |
| System accessibility (SA) | I have no difficulty accessing and using an e-learning system in the university (SA). | 5.01 (1.53) | 1.0 | n/a |

Scale: 1 = strongly disagree ~ 7 = strongly agree. All loadings were significant based on t-values.

Table 3 shows a summary of the overall model fit measures. Except for the χ^2 test result, all absolute measures were significant and considered acceptable. Since χ^2 statistics are sensitive to the number of subjects and require assumption of multivariate normal distribution, other measures are better to consider as criteria for model fitting. Truly, it is difficult to accept null hypothesis from the χ^2 test result with large sample size, even though the model fits well the collected data (Kelloway, 1998).

In addition to absolute values which are the root mean squared residual (RMR), the root mean squared error of approximation (RMSEA), the goodness-of-fit index (GFI), and the adjusted goodness-of-fit index (AGFI), NFI as comparative fit measures, and the critical N (CN) were examined. NFI ranges from 0 to 1, with values exceeding .9 indicating a good fit (Bentler & Bonnet, 1980). CN is a simple index and tentative acceptance criterion that, by focusing on sample size, provides an improved method for assessing goodness-of-fit (Hoelter, 1983). CN favors often large samples over small ones (Bollen, 1990). The researcher included this measure because of the relatively large size of the sample, 628. A fixed cutoff value is 200, and above 200 is generally regarded as a good fit to the data. Assessing all measures, the full general structural model was accepted and believed to be good enough to analyze the parameter estimates.

The general structural model was used to test the simple bivariate relationships between the constructs included in the model. Hypotheses testing was conducted within the context of the structural model. This simplified the interpretation of the results because a relationship between two constructs could be examined while holding constant other constructs in the model.

Table 3. Goodness-of-fit measures for SEM

| Fit measures | Values | Recommended value |
|--------------|---------------------|-------------------|
| χ^2 | 223.4 ($p = .00$) | $p > .05$ |
| RMR | .033 | $< .05$ |
| RMSEA | .045 | $< .10$ |
| GFI | .959 | $> .90$ |
| AGFI | .937 | $> .90$ |
| NFI | .972 | $> .90$ |
| CN | 363.880 | > 200 |

Gamma (from exogenous construct to endogenous construct) and Beta (from endogenous construct to endogenous construct) estimates which were statistically significant are denoted by asterisks. A t -value was used as a criterion to test the significance of the parameters at the .05 level. A t -value was defined as the ratio between the parameter estimate and its standard error (Jöreskog & Sörbom, 1989). T -values larger than two in magnitude were judged to be significantly different from zero in this study. A t -value larger than three was represented by two asterisks, while one asterisk represented a t -value between two and three.

Hypotheses were examined by confirming the presence of a statistically significant relationship in the predicted direction. As far as behavioral intention is concerned, attitude, e-learning self-efficacy, and subjective norms were identified to be significant. In terms of attitude, perceived usefulness, perceived ease of use, and subjective norms turned out to be significant. System accessibility had no effect on perceived usefulness. On the other hand, subjective norm had no significant relationship with perceived ease of use. The parameter estimates for the hypothesized paths, their t -values, and result of hypotheses are summarized in Table 4.

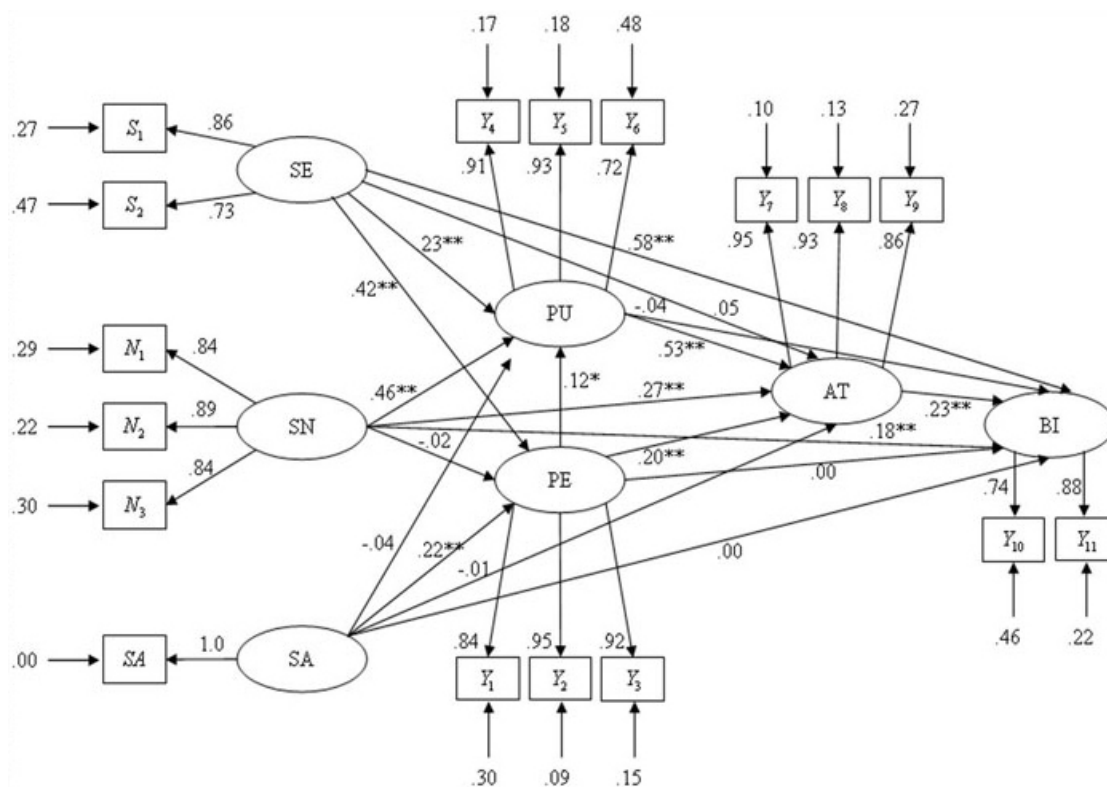


Figure 3. Parameter estimates of general structural model

Several trends were evident in the magnitude of the bivariate relationships proposed by the model. In the context of behavioral intention, key endogenous constructs of the study, all the relationships among the constructs were significant except parameter estimates from perceived usefulness, perceived ease of use, and system accessibility to

behavioral intention to use. The strongest magnitude was found in a relationship between e-learning self-efficacy and behavioral intention ($\gamma_{41} = .58$), followed by attitude ($\beta_{43} = .23$).

In contrast, both perceived usefulness and perceived ease of use were found significant in affecting user attitude. Perceived usefulness ($\beta_{32} = .53$) had the largest effect on user attitude. According to the direct effect estimates, the subjective norm was identified as the largest determinant to perceived usefulness ($\gamma_{22} = .46$), and e-learning self-efficacy had the largest effect on perceived ease of use ($\gamma_{11} = .42$). Finally, system accessibility was found to be non-significant to all constructs except perceived ease of use.

Considering the above statements, e-learning self-efficacy was the most important variable, followed by subjective norm, in influencing behavioral intention to use e-learning. In fact, these constructs were also identified as important to attitude, according to the total effect estimates.

Table 4. Parameter estimates, t-value, and results of hypotheses

| Hypothesized path | Standardized estimate | | | | Result of hypotheses |
|--|-----------------------|-----------|-----------------|--------------|----------------------|
| | Direct effect | (t-value) | Indirect effect | Total effect | |
| AT \rightarrow BI (H ₁₁) | .225 | (3.31 **) | | .225 | Supported |
| PU \rightarrow BI (H ₁₂) | -.04 | (-.60) | .118 | .082 | Not supported |
| PE \rightarrow BI (H ₁₃) | .002 | (.10) | .052 | .057 | Not supported |
| SE \rightarrow BI (H ₁₄) | .579 | (7.08**) | .054 | .633 | Supported |
| SN \rightarrow BI (H ₁₅) | .184 | (3.44**) | .096 | .280 | Supported |
| SA \rightarrow BI (H ₁₆) | .002 | (-.12) | .006 | .00 | Not supported |
| | | | | | |
| PU \rightarrow AT (H ₂₁) | .526 | (11.36**) | | .526 | Supported |
| PE \rightarrow AT (H ₂₂) | .199 | (5.57**) | .052 | .251 | Supported |
| SE \rightarrow AT (H ₂₃) | .049 | (1.11) | .229 | .278 | Not supported |
| SN \rightarrow AT (H ₂₄) | .265 | (6.49**) | .238 | .503 | Supported |
| SA \rightarrow AT (H ₂₅) | -.01 | (-.30) | .036 | .021 | Not supported |
| | | | | | |
| PE \rightarrow PU (H ₃₁) | .116 | (2.65*) | | .116 | Supported |
| SE \rightarrow PU (H ₃₂) | .234 | (3.96**) | .049 | .283 | Supported |
| SN \rightarrow PU (H ₃₃) | .461 | (9.17**) | .238 | .459 | Supported |
| SA \rightarrow PU (H ₃₄) | -.04 | (.93) | .026 | -.011 | Not supported |
| | | | | | |
| SE \rightarrow PE (H ₄₁) | .422 | (6.78**) | | | Supported |
| SN \rightarrow PE (H ₄₂) | -.02 | (-.36) | | | Not supported |
| SA \rightarrow PE (H ₄₃) | .222 | (6.19**) | | | Supported |

Conclusion and discussion

Similar to earlier studies (Lee, Cheung, & Chen, 2005; Saadé, Nebebe, & Tan, 2007), this study confirmed TAM to be a useful theoretical model in helping to understand and explain behavioral intention to use e-learning. Results of the present research led to the conclusion that the model well represented the collected data according to the result of goodness-of-fit test.

One of interesting results of the study is that both e-learning self-efficacy and subjective norm play an important role in affecting attitude towards e-learning and behavioral intention to use e-learning. One possible explanation for this may be justified by motivational theory. E-learning self-efficacy may be considered an intrinsic motivational factor and subjective norm may be an extrinsic motivational factor that could help the university students self-regulate their motivation on e-learning. According to Bandura's social motivational theory, higher self-efficacy results in a more active learning process (1994). On the other hand, subjective norm under the social influence factor pertains to behaviors that are engaged in response to recognition of other people. In Korea, people are encouraged to use IT in every field to catch up with the social change caused by IT. University students may want to adopt e-learning because they think e-learning experience will be beneficial for future job preparation. Or, they feel emotionally afraid of falling behind other students who use e-learning, if they don't take e-learning courses.

System accessibility as an organizational factor was not dominant exogenous construct affecting all endogenous construct except perceived ease of use. This may be a natural result because Korea has a developed infrastructure of IT and almost 95 percent of those in the study's sample have high-speed Internet at home. Hence, it doesn't matter whether the university provides easy access to the student or not. In fact, Konkuk University has already set up ubiquitous learning infrastructure with WIBRO technology for e-learning.

In the context of endogenous constructs, neither perceived usefulness nor perceived ease of use had a significant direct effect on behavioral intention to use e-learning. According to the original TAM, perceived usefulness is hypothesized to affect intention to use, and perceived ease of use is not hypothesized to directly affect intention. Some parts of this research were consistent with previous research, whereas some parts were contrary to previous results. One possible clue is, nowadays, learning to use the Internet is normally considered easy and the benefits from learning through Internet are already well known to students in Korea. Many university students gained enough experience in e-learning through the government (EDUNET, <http://edunet4u.net> and EBS, <http://ebs.co.kr>) during their high-school days. Therefore, both cognitive constructs could not directly affect the university students' intention to use e-learning. Rather, those constructs affected attitude towards e-learning and their attitudes affected intention to use.

The result of the study demonstrated that some TAM constructs had a direct and indirect effect on university students' behavioral intention to use e-learning. For that reason, there is potential for practical application in the development and management of e-learning in university. First, educators and managers should make an effort in boosting university students' e-learning self-efficacy. Both on- and off-line support should be provided to build up e-learning self-efficacy. In Konkuk University, an e-learning introduction, e-learning manuals, and an e-learning strategy developed by the Center for Teaching and Learning would be good examples.

Second, subjective norm is the second most important construct that affects both behavioral intention and attitude towards e-learning. Therefore, it is necessary for the university to put more emphasis on e-learning by offering a greater variety of e-learning courses and advertising the benefits of e-learning to attract students.

Third, even though perceived usefulness and ease of use had no direct effect on university students' intention to use e-learning, these constructs were related to the attitudes toward e-learning. Overlooking these constructs could have detrimental effects on the user's acceptance of information technology. Thus, it is necessary that managers and developers of e-learning help students confirm or increase their perception positively through e-learning. One possible solution is to develop more user-friendly and user-oriented e-learning content and LMS. This kind of system will add new perception to the previous attitude and thus bring about more satisfaction. This satisfaction in turn encourages students to optimistically make further use of e-learning.

Finally, this type of research needs to be implemented in other e-learning circumstances or infrastructures. Since the result of the study was limited to only 100 percent asynchronous e-learning, researchers may conduct similar studies to deal with blended learning or synchronous e-learning. Since little research has been done with those types of e-learning, it is highly recommended to carry out research employing TAM.

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Appendix A — Correlation matrix between constructs

| Constructs | BI | AT | PE | PU | SE | SN | SA |
|---------------------------------|------|------|------|------|------|------|------|
| Behavioral Intention (BI) | 1.00 | | | | | | |
| Attitude toward e-learning (AT) | .644 | 1.00 | | | | | |
| Perceived ease of use (PE) | .440 | .465 | 1.00 | | | | |
| Perceived usefulness (PU) | .556 | .776 | .347 | 1.00 | | | |
| E-learning self-efficacy (SE) | .786 | .561 | .510 | .528 | 1.00 | | |
| Subjective norm (SN) | .624 | .661 | .275 | .610 | .543 | 1.00 | |
| System accessibility (SA) | .361 | .288 | .402 | .246 | .440 | .288 | 1.00 |

Appendix B — Correlation matrix between observed indicators

| Indicator | B1 | B2 | A1 | A2 | A3 | U1 | U2 | U3 | E1 | E2 | E3 | S1 | S2 | N1 | N2 | N3 | SA |
|-----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| B1 | 1.0 | | | | | | | | | | | | | | | | |
| B2 | .65 | 1.0 | | | | | | | | | | | | | | | |
| A1 | .40 | .53 | 1.0 | | | | | | | | | | | | | | |
| A2 | .43 | .56 | .89 | 1.0 | | | | | | | | | | | | | |
| A3 | .42 | .52 | .81 | .80 | 1.0 | | | | | | | | | | | | |
| U1 | .38 | .46 | .67 | .64 | .60 | 1.0 | | | | | | | | | | | |
| U2 | .36 | .44 | .69 | .67 | .61 | .85 | 1.0 | | | | | | | | | | |
| U3 | .30 | .40 | .57 | .55 | .51 | .65 | .66 | 1.0 | | | | | | | | | |
| E1 | .38 | .38 | .47 | .38 | .40 | .35 | .33 | .28 | 1.0 | | | | | | | | |
| E2 | .35 | .33 | .44 | .35 | .39 | .29 | .28 | .23 | .80 | 1.0 | | | | | | | |
| E3 | .35 | .33 | .42 | .35 | .37 | .29 | .30 | .22 | .76 | .88 | 1.0 | | | | | | |
| S1 | .52 | .60 | .47 | .46 | .39 | .43 | .42 | .35 | .42 | .35 | .38 | 1.0 | | | | | |
| S2 | .43 | .46 | .37 | .35 | .36 | .33 | .32 | .29 | .44 | .39 | .43 | .62 | 1.0 | | | | |
| N1 | .38 | .50 | .54 | .55 | .53 | .48 | .47 | .39 | .28 | .23 | .21 | .43 | .28 | 1.0 | | | |
| N2 | .36 | .48 | .53 | .55 | .52 | .49 | .50 | .41 | .25 | .20 | .19 | .44 | .30 | .74 | 1.0 | | |
| N3 | .35 | .48 | .50 | .51 | .49 | .47 | .46 | .37 | .25 | .23 | .21 | .39 | .28 | .70 | .75 | 1.0 | |
| SA | .31 | .30 | .26 | .27 | .29 | .24 | .21 | .20 | .37 | .38 | .36 | .34 | .39 | .24 | .25 | .25 | 1.0 |

Priorities in K–12 Distance Education: A Delphi Study Examining Multiple Perspectives on Policy, Practice, and Research

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ABSTRACT

The Delphi Method of group communication was used with experienced distance education stakeholders in the United States from the areas of research, policy, and practice to identify priorities in K–12 distance education over the next five years. Data from the three rounds of this study were organized and compared using descriptive statistics. The results of the analyses by statement and by subscale indicated no significant differences among the policy, research, and practice subgroups ($p > .05$), indicating that experts identified common priorities. Delphi panel members advocated the following priority areas for K–12 distance education over the next five years (in order of importance): 1) evaluation of course design and delivery, 2) best practice, 3) accountability, 4) access, 5) online learning/learners, 6) professional development, 7) accreditation/standards, 8) funding, and 9) technology. Results of this study provide a framework of specific priority areas to be addressed by those engaged in all facets of K–12 distance education.

Keywords

Distance education, Online learning, E-learning, Virtual schools, K–12

The landscape of K–12 public education is changing substantially. Recent trends in United States policy (Hassel & Terrell, 2004; U.S. Department of Education, 2004) support the continued expansion of distance learning opportunities aimed at elementary- and secondary-school students. As pressure on decision-makers to implement distance learning opportunities for K–12 students continues to grow, so do questions concerning the effectiveness and scalability of existing programs, and the costs, needs, and barriers in creating new programs (Freedman, Darrow, & Watson, 2002). The decisions made today have lasting impact not only on our educational system but also on the individual students served. Therefore, it is imperative that development and growth occur in a thoughtful and systematic way (Blomeyer, 2002). Long-term strategic thinking about how best to adapt, adopt, and implement distance education into existing educational structures is necessary to ensure the most effective use of institutional resources and optimal outcomes for student success (Sarason, 1990; Verduin & Clark, 1991). The purpose of this three-round Delphi study was to identify and facilitate the prioritization of issues surrounding this rapidly evolving field.

Background

Distance education as defined by the National Center for Educational Statistics (NCES) is “education or training courses delivered to remote (off campus) location(s) via audio, video (live or prerecorded), or computer technologies, including both synchronous and asynchronous instruction” (1999, p. 2). Web- or Internet-based education is a form of distance education that uses the Internet for content delivery. Virtual schools and programs that utilize Internet-based technologies often fall into these pre-existing definitions of distance education. E-learning or online learning is a subset of distance education that specifically incorporates web-based or Internet technologies (Simonson, Smaldino, Albright, & Zvacek, 2006).

Distance education in the form of online courses and programs targeting grade levels K–12 are often referred to as “virtual schools” or “cyber-schools” and operate in a variety of ways. They can be operated by public school districts and other local education agencies, by state education agencies, by colleges and universities, as cyber charter schools, by regional agencies, by consortia of educational entities, and as nonprofit and for-profit organizations. Regardless of how virtual schools are operated, the rise in the number of virtual schools has been dramatic. Forty-two states currently offer either state supplemental programs, full-time online programs, or both, with enrollment growth between 25 and 50 percent (Watson & Ryan, 2007) and indications that every state now has some form of cyber-school operating within its boundaries (Long, 2004).

Distance education programs may provide additional choices for high educational achievement of every child, but the challenge is to ensure that this alternative form of instruction increases the quantity of educational opportunities while maintaining or enhancing the quality of those opportunities (Roblyer & Marshall, 2003). Educators and policymakers look to researchers to provide evidence of effectiveness to assist in planning for future events and to inform classroom practice (Roybler & Knezek, 2003). Researchers may follow the lead of visionary policymakers in defining research agendas. And neither policy nor research will be effective if there is no perceived value in the adaptation and application of policy and research decisions in the classroom. Whether or not K–12 distance education programs improve educational opportunities provided to students will depend upon the identification of priorities from the multiple perspectives of these critical stakeholders.

Methodology

This study used the Delphi method (Linstone & Turoff, 1975; Ziglio, 1996) to identify priorities for K–12 distance education policy, practice, and research over the next five years. Three questions guided the collection and analysis of data:

1. What should be the research, practice, and policy priorities surrounding K–12 distance education over the next five years?
2. What are the differences and/or similarities between the perspectives of researchers, practitioners, and those who are in a position to influence policy?
3. What are the implications of these similarities/differences for the planning and implementation of K–12 distance education programs?

Originally developed at the Research and Development Corporation (RAND) in the 1950s as a systematic methodology for examining likely futures, the Delphi method was initially used in forecasting technological innovations and the social and economic impact of technological change (Brown, 1968; Ziglio, 1996). Since that time, the Delphi method has been used to obtain consensual and consistent opinions from experts and has been employed in a variety of fields, such as health care (Dawson & Brucker, 2001; Powell, 2002), business, policy (Linstone & Turoff, 1975), and education (Herring, 2004; Pollard & Pollard, 2004). The Delphi method represents a systematic approach to the data-gathering process. First, it is a structured process of group communication. Second, it allows for the quantitative assessment of group opinion and disagreement. Third, it enables respondents to participate anonymously. Finally, the Delphi process of group communication provides an avenue for a thoughtful analysis of practice, policy, and research goals from individuals in positions of authority, experience, and knowledge of the field (Adler & Sainsbury, 1996; Linstone & Turoff, 1975; Ziglio, 1996).

All Delphi studies must maintain three critical components: 1) anonymity, 2) structured information flow, and 3) controlled feedback, typically in the form of descriptive statistics. In addition, the Delphi method is particularly useful when

- the problem does not lend itself to precise analytical techniques but can benefit from subjective judgments on a collective basis.
- the individuals need to contribute to the examination of a broad or complex problem, have no history of adequate communication, and may represent diverse backgrounds with respect to experience or expertise.
- More individuals are needed than can effectively interact in a face-to-face exchange.
- The heterogeneity of the participants must be preserved to assure validity of the results, that is, avoidance of domination by quantity or by strength of personality (“bandwagon effect”) (Linstone & Turoff, 1975, p. 4).

To encourage a broad range of potential priorities, this study sought input from three disparate professional areas, each with a specialized area of expertise (Anderson & Kanuka, 2003; Ziglio, 1996). The three expert subgroups consisted of the following: 1) practitioners engaged in the day-to-day operations of distance learning ($n = 10$), 2) those influential in creating policy or making policy decisions that directly affect distance education programs or schools ($n = 11$), and 3) those engaged in research activities in distance education ($n = 8$). Data was collected over a three-month period in the fall of 2005. A letter of invitation to participate in this study was sent by electronic mail to 86 potential participants (within the United States) identified through a search of state-level technology administration websites, university websites, websites associated with virtual schools and programs, and a thorough review of the literature. Twenty-nine respondents, from 12 states, became the participants for the Round One questionnaire.

Results

Round One, Two, and Three Results

In Round One, 29 expert panel members generated 149 total statements that were coded and consolidated into 96 statements. Statements were also organized into nine subscales. To reduce threats to internal validity, a peer checking process was used to code the open-ended responses (Krathwohl, 1998). The two analyses were then compared and any differences were resolved with the assistance of a third objective rater. Individual statement importance was rated, and subscales were ranked by panel members in subsequent rounds. Panel members were also given the opportunity to comment on each item during the Round Three iteration of the study.

Data from the three rounds of this study were organized and compared using descriptive statistics. A summary of the total and consolidated responses arranged by nine priority areas or subscales (in alphabetical order) is presented in Table 1.

Table 1. Number of Round One responses by subscale

| Subscale | All statements | Consolidated statements |
|---|----------------|-------------------------|
| 1. Access | 12 | 10 |
| 2. Accountability | 11 | 8 |
| 3. Accreditation/standards | 14 | 6 |
| 4. Best practice | 34 | 16 |
| 5. Evaluation of course design and delivery | 9 | 8 |
| 6. Funding | 13 | 6 |
| 7. Online learning/learners | 23 | 17 |
| 8. Professional development | 19 | 11 |
| 9. Technology | <u>14</u> | <u>14</u> |
| Total | 149 | 96 |

Comparison of individual items from Rounds Two and Three

In Delphi studies, the same questionnaire is used in both Round Two and Round Three. The data from Round Three are considered the final results, but the results from Round Two can be used to illustrate potential convergence between rounds. Table 2 displays the distribution of mean scores for all items on the questionnaire for Round Two and Round Three. The mean scores from the responses of 36 of the 96 questionnaire items increased from Round Two to Round Three.

Table 2. Frequency distribution of mean scores for all items from Rounds Two and Three

| Mean Score ^a | Round 2 | | Round 3 | | Net Change |
|-------------------------|-----------|------------|-----------|------------|------------|
| | Frequency | Percent | Frequency | Percent | |
| ≥ 4.50 | 0 | 0.0 | 2 | 2.1 | +2 |
| ≥ 4.00 < 4.50 | 14 | 14.6 | 11 | 11.5 | -3 |
| ≥ 3.50 < 4.00 | 49 | 51.0 | 45 | 46.9 | -4 |
| ≥ 3.00 < 3.50 | 28 | 29.2 | 30 | 31.3 | +2 |
| ≥ 2.50 < 3.00 | 5 | 5.2 | 8 | 8.2 | +3 |
| ≥ 0 < 2.50 | <u>0</u> | <u>0.0</u> | <u>0</u> | <u>0.0</u> | <u>0</u> |
| Total | 96 | 100 | 96 | 100 | 0 |

^a Responses were rated on a scale of 1 to 5, with 1 = no importance, 2 = low importance, 3 = medium importance, 4 = high importance, 5 = very high importance.

Consistency between rounds is illustrated in Table 3, which contains descriptive statistics for the items rated as having very high importance ($M \geq 4.00$) in Round Three and the corresponding ratings in Round Two. Ten of the 14 items from Round Three were also rated as having very high importance in Round Two. In addition, there was an overall increase in mean scores from Round Two to Round Three and a corresponding decrease in standard

deviations. These highly rated items included responses from seven of the nine identified subscales. No mean response values from items in the subscales of professional development or technology met the criteria for highest-rated responses. The overlap in content from one subscale to another might explain their exclusion. For example, the subscales of best practice and funding contain responses that imply the necessity of professional development funding and the need for technological resources. Two of the highest-rated items were from the best practice subscale, providing further evidence of the importance this panel placed on identifying effective pedagogical practices of online teachers in the K–12 environment.

It should be noted that although the original research questions used the terminology “K–12 distance education,” an overwhelming number of responses specifically referred to “online” or “virtual” courses and programs. This slight shift in usage was left intact in order to present panel members’ intent as closely as possible.

Table 3. Comparison of items rated “high importance” to “very high importance” ($M \geq 4.00$) from Round Three (R3) and corresponding ratings from Round Two (R2)

| Subscale | Statement | R3 Rank | R3 <i>M</i> | R3 <i>SD</i> | R2 Rank | R2 <i>M</i> | R2 <i>SD</i> |
|----------------------|---|------------|----------------|-----------------|------------|----------------|-----------------|
| Best practice | Defining the characteristics of effective pedagogical and technological applications that lead to achievement gains. | 1 | 4.59 | .57 | 2 | 4.36 | .73 |
| Account | Making virtual schools as accountable as brick-and-mortar schools. | 2 | 4.52 | .89 | 1 | 4.36 | .73 |
| Access | Removing state-level barriers to the establishment and operation of virtual public schools as a legitimate choice within a state’s public education system. | 3 | 4.22 | .89 | 7 | 4.07 | 1.05 |
| Best practice | Identifying effective pedagogical practices in the distance learning environment. | 4 | 4.16 | .80 | 8 | 4.07 | .60 |
| Access | Studying relative accessibility, equity, and quality of online programs. | 5 | 4.15 | .66 | 10 | 4.04 | .98 |
| Accred. | Aligning online courses and curriculum to states’ academic standards. | 6 | 4.15 | .66 | 3 | 4.21 | .74 |
| Accred. ^a | Offering an accredited program. | 7 | 4.11 | .70 | 20 | 3.89 | .80 |
| Access ^a | Providing an education for those students and families who are in unusual situations such as traveling, dealing with a long illness, living in remote areas, running businesses, etc. | 8 | 4.07 | .62 | 37 | 3.71 | .94 |
| Accred. | Offering a high-school program that is accredited by the state that is providing the program. | 9 | 4.07 | .96 | 6 | 4.12 | .082 |
| Eval. | Developing a comprehensive and effective method for evaluating the effectiveness of teaching and learning in an online K–12 school. | 10 | 4.04 | .60 | 5 | 4.18 | .67 |
| Eval. | Researching effective online course design and delivery. | 11 | 4.04 | .59 | 9 | 4.07 | .81 |

| | | | | | | | |
|------------------------------|---|----|------|-----|----|------|-----|
| Online learning/ Learners | Educating the public as to what distance learning is, what the purpose is, and why it may be a method for some children while not for others. | 12 | 4.04 | .65 | 11 | 4.04 | .98 |
| Funding ^a | Providing financial resources for the extensive training of teachers and administrators of online K–12 schools in order to assure that effective teaching and learning is taking place. | 13 | 4.00 | .96 | 24 | 3.85 | .99 |

^a Indicates an item not rated “very high importance” ($M \geq 4.00$) in Round Two.

The lowest rated items from Round Three ($M \leq 3.00$) and the corresponding ratings from Round Two are presented in Table 4. Seven of the nine items included in this category were also rated similarly in Round Two.

Table 4. Comparison of lowest rated items ($M \leq 3.00$) from Round Three and corresponding items from Round Two

| Subscale | Statement | R3 Rank | R3 <i>M</i> | R3 <i>SD</i> | R2 Rank | R2 <i>M</i> | R2 <i>SD</i> |
|------------------------------|--|------------|----------------|-----------------|------------|----------------|-----------------|
| Online learning/ Learners | Ability as a field of study to provide a synthesis of principles and concepts capable of explaining and predicting developments in the 21st century. | 1 | 2.52 | 1.05 | 2 | 2.81 | 1.24 |
| Best practice | Enrichment opportunities to stretch the curriculum through student activities such as chess clubs, research teams, study groups, reading buddies, or student-to-student mentors. | 2 | 2.70 | .78 | 1 | 2.74 | .90 |
| Online learning/ Learners | Information literacy studies. | 3 | 2.70 | 1.03 | 3 | 2.85 | 1.03 |
| Tech. | Technology safety: Examine the obligation of distance education providers to deal with issues associated with the Internet (i.e., spyware, malware, pop-ups, and unwanted IMs, etc.) and the associated costs. | 4 | 2.74 | .66 | 6 | 3.04 | .90 |
| Online learning/ Learners | Examination of student development issues | 5 | 2.78 | .85 | 5 | 2.96 | 1.00 |
| Eval. | Research into commercial elementary virtual providers’ models, effectiveness, socialization of students, etc. | 6 | 2.85 | .82 | 15 | 3.32 | 1.02 |
| Tech. | Development of classes that reach students with the lowest connection speed | 7 | 2.93 | .68 | 9 | 3.22 | .85 |
| Tech. | Use of e-texts | 8 | 2.96 | .87 | 4 | 2.89 | 1.05 |
| Account. | Exploration of how student, teacher, school, and program data may be made interchangeable and accessible to promote large-scale comparisons | 9 | 3.00 | .92 | 21 | 3.39 | 1.10 |

Comparison of priority areas from Rounds Two and Three

In addition to the individual ratings within each subscale, respondents were also asked to rank the importance of the subscales relative to each other. The rankings for the nine subscales from Round Three and the corresponding rankings from Round Two are presented in Table 5. The rankings from Round Two to Round Three are virtually identical, with the exception of the Accreditation/Standards subscale, which fell from a Round Two ranking of four to a Round Three ranking of seven. An examination of the results demonstrates a reduction in standard deviation values for all subscales from Round Two to Round Three.

Table 5. Round Three priority areas' rankings and corresponding rankings from Round Two

| Priority area ^a | R3 | R3 | R3 | R2 | R2 | R2 |
|--|------|----------|-----------|------|----------|-----------|
| | Rank | <i>M</i> | <i>SD</i> | Rank | <i>M</i> | <i>SD</i> |
| Evaluation of course design and delivery | 1 | 2.62 | 1.75 | 1 | 4.07 | 2.06 |
| Best practice | 2 | 3.65 | 2.43 | 2 | 4.11 | 2.68 |
| Accountability | 3 | 3.81 | 1.92 | 3 | 4.33 | 2.34 |
| Access | 4 | 3.88 | 2.12 | 5 | 4.96 | 2.74 |
| Online learning/learners | 5 | 5.96 | 1.68 | 6 | 5.22 | 2.33 |
| Professional development | 6 | 6.08 | 1.67 | 7 | 5.37 | 2.31 |
| Accreditation/standards | 7 | 6.19 | 2.12 | 4 | 4.89 | 2.91 |
| Funding | 8 | 6.50 | 2.18 | 8 | 5.70 | 2.49 |
| Technology | 9 | 8.19 | 1.67 | 9 | 6.33 | 2.79 |

^a Respondents were asked to rank each area in order of priority from 1 = highest priority to 9 = lowest priority.

Subgroup analysis

Data were analyzed to determine whether membership in a particular subgroup resulted in any important differences in the responses to individual statements using the Kruskal-Wallis H test, the nonparametric equivalent of the one-way analysis of variance test (Huck, 2004). The results of the subgroup analyses in both Rounds Two and Three indicated no significant differences between subgroups for any of the individual statement importance ratings ($p > .05$).

In addition to analyses of responses to individual statements, mean responses within the nine major subscales were generated and analyzed to determine if there were differences among subgroup responses. The means and standard deviations presented in Table 6 illustrate the similar responses among groups on all subscales.

Table 6. Means and standard deviations for subscales by subgroup, in order of rank

| Subscales | Research | | Subgroup policy | | Practice | |
|--|----------|-----------|--------------------|-----------|----------|-----------|
| | <i>M</i> | <i>SD</i> | <i>M</i> | <i>SD</i> | <i>M</i> | <i>SD</i> |
| Evaluation of course design and delivery | 3.57 | .28 | 3.54 | .52 | 3.51 | .40 |
| Best practice | 3.76 | .34 | 3.55 | .50 | 3.63 | .43 |
| Accountability | 3.70 | .52 | 3.81 | .55 | 3.68 | .47 |
| Access | 3.61 | .28 | 3.52 | .37 | 3.67 | .25 |
| Online learning/learners | 3.53 | .31 | 3.31 | .59 | 3.45 | .48 |
| Professional development | 3.70 | .55 | 3.69 | .58 | 3.56 | .51 |
| Accreditation/standards | 3.81 | .57 | 3.92 | .47 | 4.02 | .40 |
| Funding | 3.74 | .59 | 3.47 | .49 | 3.48 | .49 |
| Technology | 3.47 | .48 | 3.15 | .50 | 3.34 | .50 |

Part Two of the questionnaires asked panel members to rank the priority of each subscale on a scale from one (highest) to nine (lowest). These rankings were also analyzed using the Kruskal-Wallis H test. No significant differences were detected among the subgroups in either Round Two or Round Three.

Discussion

Delphi panel members advocated the following priority areas for K–12 distance education over the next five years (in order of ranking):

1. Evaluation of course design and delivery — research on effective online course design and delivery, and development of a comprehensive and effective method for evaluating that effectiveness.
2. Best practice — define and identify characteristics of effective pedagogical practices and technological applications that lead to achievement gains.
3. Accountability — hold virtual schools to the same accountability requirements as brick-and-mortar schools.
4. Access — increase access to distance education programs for all students by removing state-level barriers to the establishment and operation of virtual public schools, developing programs to better assist special needs students, and implementing statewide open enrollment policies.
5. Online learning/learners — educate the public about the function and purpose of distance education while increasing awareness of the potential advantages and disadvantages distance learning opportunities may present to learners.
6. Professional development — ensure that online instructors have the proper training to be effective teachers in the online environment, perhaps in the form of a credential or certificate.
7. Accreditation/standards — align online courses and curriculum to states' academic standards and offer an accredited program.
8. Funding — ensure that effective teaching and learning is taking place by providing financial resources for the extensive training of teachers and administrators of online K–12 schools or programs.
9. Technology — improve high-speed access to allow more engaging online learning while examining those tools and processes that make teachers more successful, efficient, and productive.

Evaluation of course design and delivery

Although the subscale of evaluation of course design and delivery received the fewest number of responses in Round One, it was ranked as the highest priority by the panelists as a whole. Panel members proposed that research on effective online course design and delivery and on the development of a comprehensive and effective method for evaluating that effectiveness are of high priority for the future of K–12 distance education. Research supports this finding and advocates the use of program evaluations as a tool in both policy development and implementation (Watson, 2005). A comprehensive study conducted by the University of California College Preparatory Initiative examined the condition of virtual high schools both within the state and across the country and is one example of the value of evaluation data. By looking at multiple aspects of online education across a wide number of programs — course development, instruction, growth, state policies, program organization, and technologies — researchers were able to construct a model to guide the development of online education in the state (Freedman et al., 2002). Dickson (2005) agrees, and suggests that an organized and consistent data collection system be a high priority at the start-up phase of any distance education program. The benefits of such a system are far reaching, especially if standard forms of data collection across programs are implemented.

Research in the area of commercial providers was rated as medium to low importance. This may indicate that panelists viewed evaluation of all programs as important rather than singling out one type of program for investigation. One panelist suggested that this area is of interest, but “the greater need is higher grades where so many more students are currently impacted.” In addition, panel members cited the need to differentiate between online learning instruction and delivery models when conducting research and evaluations as well as the need to examine the conditions of use. This finding reiterates the message from the research regarding the limitations of comparative studies focusing extensively on outcomes (Bernard, Abrami, Lou, & Borokhovski, 2004; Cavanaugh, 2001; Cavanaugh, Gillan, Kromrey, Hess, & Blomeyer, 2004).

Best practice

The area of best practice was the second-highest ranked priority area overall. The statement “Defining characteristics of effective pedagogical and technological applications that lead to achievement gains” was the highest-rated item

within this category as well as the highest-rated item of all responses ($M = 4.59$). However, strictly focusing on student outcomes caused one panel member to comment that

Measuring student outcomes has often been the focus of research in this area. However, factors that can contribute to student learning (e.g., instructional strategies employed, student motivation, teacher/student interaction, etc.) have been overlooked because they are difficult to control and measure. Can research be designed to effectively measure these types of contributing factors?

Researchers continually argue for more research into the specific factors associated with effective programs (Ferdig, DiPietro, & Papanastasiou, 2005; Roblyer & Knezek, 2003). While developments continue to be made in developing and documenting promising practices (Watson & Ryan, 2007), a systematic investigation of the critical components of successful programs is necessary, not only to ensure success for students, but also to inform policy.

Panel members also cited the need for “research into what works best for high school, middle school, and elementary school,” indicating the need to differentiate and expand the research base from a focus on adult learners to a focus on younger learners. Although much research has been done in the context of adult learners, very little has been done with younger students. This is an important consideration when making decisions, because young learners can be fundamentally different from adults, both cognitively and emotionally (Cavanaugh, et al., 2004).

The adult research base provides a starting point, but it has not established an ideal record in terms of quality (Bernard, Abrami, Lou, & Borokhovski, 2004; Phipps & Merisotis, 1999). Current K–12 distance research efforts attempt to ameliorate the difficulties found in adult research by focusing on quality studies that examine predictive characteristics (Roblyer & Marshall, 2003; Simpson, 2004), the impact of professional development and student perception on outcomes (Hughes, McLeod, Brown, Maeda, & Choi, 2005), and the value of student-to-student interactions in online courses (Zucker, 2005). However, qualitative, descriptive studies still represent the greatest amount of research to date. This focus on descriptive research is apparent in studies exploring learner supports (Frid, 2001), teacher-to-student interaction (Vrasidas & Zembyas, 2003), and quantity and quality of interactions with the use of synchronous communication tools (Murphy & Coffin, 2003).

In addition to general statements regarding effective practices, respondents also indicated the importance of creating partnerships with parents and offering individualized instruction based on student needs. Finally, panel members indicated that consideration should be given to practices specific to distance education. These include creating collaborative environments through the use of various synchronous and asynchronous technologies, community building, research analyzing interaction types, and consideration of student to teacher ratios.

Accountability

Holding virtual schools to the same accountability requirements as brick-and-mortar schools was seen as a high-priority area. The accountability subscale received the third-highest priority ranking overall and the statement “virtual schools should be as accountable as brick-and-mortar schools” received the second-highest ranking of all statements from the Round Three survey instrument ($M = 4.52$). This finding seems appropriate considering the influence of national and state-level accountability requirements in all areas of education (U.S. Department of Education, 2001). However, one panel member cautioned:

As a simple statement of policy, I agree strongly with the notion that virtual schools should be as accountable as B & M [brick & mortar] schools. My own experience is that most virtual schools (at least full-time schools) are as accountable, if not more so, than typical B & M schools. I would not be supportive of placing more accountability on virtual schools than is placed on B & M schools.

In addition to the same accountability requirements, panel members thought it was important to establish that online learning situations are of the same quality as face-to-face but were less inclined to do this through comparison studies. Panel members rated examining student performance in the distance learning environment versus the traditional face-to-face environment as less important, but this item still retained a medium- to high-importance rating. Distance programs and virtual schools are in a unique position, similar to other alternative forms of education. They have been placed in the position of not only establishing value through traditional accountability methods but they must also establish credibility through comparisons with traditional schools. The energy focused on comparative studies and the number of related statements generated in this study reflects this tension.

Access

Panel members' responses suggest that removing state-level barriers to the development of distance education programs is of high importance. Regarding this statement, one panel member commented: "Before we start removing 'barriers' we had better be very sure our students are successful. There are many psychological issues which need to be studied first." No items in this category were ranked below medium importance. The highest-rated items in the access subscale address the importance of issues related to improving not only the quantity of accessible online programs, but ensuring that programs are developed that meet the needs of the students in those programs.

Providing access to an alternative route for education is perhaps the most important aspect of distance education. It has been argued that distance education environments may offer the advantage of a more personalized and instructionally diverse educational experience. Virtual schools and programs in particular may also offer increased educational options for students who lack access to highly qualified teachers or courses that would not otherwise be available, or who are simply unsuccessful in traditional learning environments (Chaney, 2001; Setzer & Lewis, 2005). Panel member responses reflect these beliefs. Not only did they indicate the importance of removing state-level barriers to the establishment of virtual public schools but the higher-than-average number of comments in this area suggest that panel members are reluctant to restrict access by establishing rigid eligibility requirements.

The question of effectiveness is an important one in this context, especially when considering the proclivity for attracting at-risk student populations and when taking into consideration the unique requirements of special needs students. Although the research in this area is limited, the number and quality of interactions appear to be important components of student satisfaction and retention rates of adult learners (Downs & Moller, 1999; Kuh & Hu, 2001; Muirhead, 2001; Picciano, 2002; Stein, Wanstreet, Calvin, Overtoom, & Wheaton, 2005; Stith & Fitz, 1994). We also know that younger students who experience consistent, positive relationships with their teachers are more likely to persist in traditional schools (Barr & Parrett, 2001; Lee & Burkham, 2001). These findings suggest that there is the potential for greater student satisfaction in courses and programs that emphasize strengthened social supports (Passey, 2000).

The requirements of special needs students present additional challenges to distance education programs on several fronts. Panel members cited the need for the development of online programs and assistive technology that provide for the continued progress of special needs students. Although great gains have been made in assistive and adaptive technologies, little is known about their use and implementation in distance environments. In addition, special needs students often require physical access to special services. This necessitates cooperation from all levels of the educational infrastructure — from state, district, and school levels — and often entails the use of outside entities. Obviously, further research is needed to explore the benefits and drawbacks of distance education not only for these special populations of students, but for all students.

Online learning/learners

Seventeen statements were generated for the area of online learning/learners, the fifth-ranked category. Educating the public about distance learning was the highest-rated item in this area. Panel members also cited the importance of finding ways to improve the success of students interested in distance education through adaptable yet rigorous curricula, individualized instruction and assessment, support systems, and collaboration. The statement: "research into the characteristics of successful distance learning students" received some interesting comments. Two panelists from the research subgroup suggested that this type of research was "more valid than trying to define successful characteristics of the educational process" and that "this type of research could really help inform instructors who are designing learning classes." However, restricting research to identify only those characteristics found in successful learners caused one policymaker to voice the concern that "the 'ideal' student will be directed that way and others not — but different pedagogies and modalities wouldn't be included."

Professional development

The area of professional development ranked sixth in the priority rankings overall. This finding is interesting because the highest-rated item overall was a statement from the best practice subscale: "defining the characteristics of effective pedagogical and technological applications which lead to achievement gains." Also rated of high

importance to very high importance was “identifying effective pedagogical practices in the distance learning environment.” These statements imply that high importance should be placed on best practice not only for organizational programs/processes but also to ensure that teachers, who will eventually be the direct contact between the student and the technology, are provided with opportunities to develop the proper skills to effectively teach in the online environment. Although the category as a whole ranked lower on the list of priorities, panel members also rated funding for training the highest within the funding category, suggesting that this panel deems it of high priority - at least in the area of funding.

Within this area, panel members indicated that proper training of online teachers, perhaps in the form of a credential, and an examination of the necessary knowledge, skills, and dispositions of online instruction, ranked highest. This finding is supported by the National Educational Technology Plan, which stipulates that every teacher should have the opportunity to participate in e-learning training (U.S. Department of Education, 2004). However, “less than 1 percent of all teachers nationwide are trained as online teachers” (Smith, Clark & Blomeyer, 2005, p. 52). State agencies and university education programs have been slow in meeting the professional development needs of K–12 online teachers. As a result, the majority of training has been provided by the school, program, or organization with which the teacher is affiliated (Rice & Dawley, 2007).

On a national scale, the Southern Regional Education Board (SREB, 2006), the National Education Association (NEA, 2006), the North American Council for Online Learning (NACOL, 2008), and the International Society for Technology in Education (ISTE, 2008), have developed guidelines and standards that can help guide professional development activities for K–12 online teachers. The standards proposed by these regional and national organizations are similar in their emphasis on student-centered instructional environments where courses are collaborative, flexible, and facilitated by highly qualified teachers; allow multiple paths for learning; and address a variety of learning styles.

Little research specifically exploring the benefits of teacher training in distance education has been done, but other sources suggest that it continues to be a high priority for researchers (Smith et al., 2005). Knowledge about subject matter and traditional instructional approaches are as necessary for online teachers as they are for those teaching in traditional environments, but online teachers require additional knowledge in order to be able to successfully motivate and engage learners. These include qualities such as good communication skills, especially written communication skills, since many of the avenues for communication in the online environment are text-based. Quality online teaching also requires creativity in developing and delivering activities that are collaborative and highly interactive and requires teachers to be technologically capable. The latter quality alone suggests that ongoing training is necessary in order for online teachers to keep up with the most recent technological advances.

Other statements in this area suggest the need for the identification of administrative skills necessary to manage an online education program. The recent expansion of distance learning to the early elementary grades has necessitated an examination of the increasingly important role of the parent. Two items relating to this concept include providing training opportunities to learning coaches, and examining more closely the changing role of the parent as educator.

Accreditation and standards

The accreditation and standards subscale was the only area where the priority ranking changed from Round Two to Round Three (from a ranking of four to a ranking of seven). Alignment of online courses and curriculum to the states’ academic standards received the highest rating in this category. Interestingly, panel members seemed somewhat reluctant to align online course content to standards because of the perception that standards cover only the minimum requirements of proficiency and capabilities. For example, one panel member stated, “standards tend to trend practice toward mediocrity. I’d rather see ideals defined.” Another stated, “I am not sure we want to merely align with state standards given these standards may not be the best test of educated persons.” And finally a third commented, “certainly must set some requirements here, if not outright standards, which tend to cover the bare minimum competencies.”

Panel members also cited accreditation of programs as very important. Regarding the differentiation between offering an accredited program or offering a program that is accredited by the state in which the program is being provided, one panel member commented, “it is less important who does the accreditation than the details and quality

of the accreditation process.” Finally, developing policies for online course delivery across state borders received the lowest rating in this group but still retained a medium- to high-importance rating.

Funding

Only a small percentage of students in the K–12 educational system are served by distance education programs, which perhaps explains why panel members ranked funding eighth in priority overall. In fact, the only statement from the funding category that received a “high importance” to “very high importance” rating ($M \geq 4.00$) suggests that current funding initiatives should be targeted toward the training of teachers and administrators. However, if current growth is any indication, the number of students served will increase substantially in the future and the pressure to address funding issues will only intensify as expansion occurs.

Although ranked lower in importance ($3.70 \geq M \geq 3.11$), the remaining five funding statements reflect an awareness of increasing pressure to address funding issues as growth and expansion continue. For example, panel members cited the need to equalize funding between virtual schools and brick-and-mortar schools, the need for research into the cost benefits of implementing a distance learning program, and the need to work toward consensus on financing the system.

Funding of virtual schools has occurred in a variety of ways, depending on the state and the type of school. In some cases, virtual schools are funded in traditional ways based on average daily attendance. In the case of the Florida Virtual School, funding is based on course completion. Some online programs charge student fees while others provide courses free of charge. Unfortunately, it is unclear how much it costs to educate a student in a virtual school (Augenblick, Palaich, & Associates, 2005). Virtual schools often must address unique funding issues that don’t fit into traditional funding formulas. For example, many virtual schools provide such things as computers and complete curriculum packages to individual learners, something that is not typical in a traditional school setting. There are also costs associated with curriculum or course development as well as student support. On the other hand, the costs for virtual school facilities tend to be lower than those for traditional brick-and-mortar schools.

There are additional cost savings that can often be considered as well. There is the potential for the sharing of resources by tying K–12 to higher education, potential cost savings in state resources by improving the drop-out rate, and potential cost savings in accelerated graduation programs (Thomas, 2002). Fortunately, as growth continues, more and more states enter the arena providing policymakers with a diverse assortment of alternatives from which to choose. What is clear from this study is that panel members who responded with additional comments were less inclined to support policies that attempted to take funding from traditional brick-and-mortar schools as evidenced in this passage: “We need to develop funding which does not take away from brick & mortar schools.”

Technology

The lowest-ranked subscale was in the area of technology. Those items that were rated higher within this category relate to the effectiveness and efficiency of the tools used to engage in distance education. These include improving high-speed access, examining the effectiveness and improving the availability of administrative tools, and studying learning objects in relation to learners and content areas. Technology safety was ranked lowest in this area perhaps because of the perception by one panel member that “if parents are involved, they should monitor this issue.”

Although a low ranking for technology may be a surprising outcome of this investigation, caution should be taken when interpreting this finding. Despite the necessity for computer-mediated technologies in the process of online learning, the focus of this panel appeared to center around technologies in the context of effective instruction. Actually, this view makes sense given that distance education, like other more traditional forms of education, is about the learner, the teacher, the content, and the complex interactions that facilitate learning. The technologies used to deliver that instruction are merely tools to assist in enhancing those learning opportunities. In addition, the ninth-place ranking in no way suggests that the technologies used in distance education are unimportant. First, all of the subscales identified in this investigation are considered high-priority areas. Second, the technology subscale was comprised only of those statements related strictly to technological improvements independent of their current or

potential instructional applications. Statements focusing on instructional applications are contained in all of the other subscales.

Conclusion

K–12 distance education programs have the potential for impacting traditional educational purposes and processes in substantial ways. They provide access to educational opportunities where they would not otherwise exist, in an environment conducive to the development of important skills for the 21st century. Furthermore,

Beyond access, distance education gives a greater degree of control to the learner in relation to the teaching institution, with effects on what the institution offers to teach and the way it teaches. We are in the middle of a Copernican revolution as it becomes ever more apparent that the learner constitutes the center of the universe, and that teaching no longer drives learning; instead, teaching responds to and supports learning (Moore & Kearsley, 2005, p. 20).

However, rapid growth in online programs and schools has added complexity and confusion in the areas of research, policy, and practice. Although it appears as though distance education in the K–12 environment will continue to have a role in public education (Freedman et al., 2002), what that role is and how it is integrated into current systems will depend largely on a concerted effort between knowledgeable and enlightened stakeholders.

The findings from this study have been positioned with existing research findings to better reflect the status of K–12 distance education, to identify further research potential, and to identify policy and implementation recommendations. Primarily, the results are useful in that they provide a framework of priorities in K–12 distance education taken from the perspectives of three essential stakeholder groups: researchers, policymakers, and practitioners. The nine subscales identified by study participants offer a structured lens through which to view those areas of primary importance to the individuals intimately involved in facing the challenges associated with this new and innovative approach to learning.

The results of this study are also helpful in identifying future research potential. Much of the past research in distance education has focused on studies comparing student performance in distance education to student performance in face-to-face environments (Bernard, Abrami, Lou, Borokhovski, Wade, Wozney, et al., 2004; Cavanaugh et al., 2004; Phipps & Merisotis, 1999). Results from this study indicate that although comparative research studies per se are not a high priority, it appears to be important to establish that the distance learning environment is the same as or better than face-to-face learning environments. However, the possibility of ever determining whether online courses are equal to face-to-face courses seems unlikely. “The complexity in sources of variability in performance in online courses means there is little prospect of giving a definitive answer to the question of the relative superiority of online versus traditional courses” (Dickson, 2005, p. 23). More important is determining the potential impact and success of a program on student outcomes and identifying, empirically, the specific factors associated with that success.

The following recommendations for policy implementation and/or research potential are also supported by the findings from this study (in no particular order):

- Develop organized evaluation systems that examine multiple aspects of distance learning to facilitate consistent data collection. These would include elements common to all programs (i.e., attendance, retention, and student outcomes).
- Investigate the specific factors associated with effective programs: best practice, online learning environments, and the influence of learner characteristics on success. Develop processes that allow for formal documentation of these factors.
- Improve the quality of research that examines critical components of learning directly related to younger learners.
- Implement research initiatives for special needs and at-risk learners in distance education environments.
- Ensure that distance programs are as accountable as traditional programs through alignment with states’ curriculum standards and accreditation.
- Remove barriers and restrictions while ensuring that student needs are being met.

- Provide funding for training and require that distance educators possess the specific qualities necessary for success. This includes training for administrators as well as teachers. As growth continues, the need for administrators with leadership and evaluation skills in online environments will only intensify.

Panel members clearly recognize the need to identify and define the specific pedagogical, learner, and technological characteristics of successful programs. As more and more agencies explore the viability of online programs and schools, it will be the role of the research community to inform policy decisions and lead the way to establishment of standards for best practice and comprehensive program evaluation. The detailed collection and reporting of data can only begin when common goals are identified by policy makers and evaluators (Cavanaugh et al., 2004). This type of planning and forethought requires open and collaborative relationships between all stakeholders: those who approve a program, those who administer a program, and those who analyze data to determine a program's effectiveness. The results of this study suggest that stakeholders do advocate common goals and are in agreement in the establishment of a framework of priorities for the next five years. This framework is an important first step in developing constructive plans for implementation and study.

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A review of case-based learning practices in an online MBA program: A program-level case study

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ABSTRACT

This study examines how a case-based learning approach was used and facilitated in online business education. Perceptions of students and instructors regarding the practices of case-based learning in online environments are explored in terms of instructional design, facilitation, and technology support. This study finds case-based learning to be a valuable instructional method for online business students who practice authentic problem solving by applying what they learned. The study demonstrates that case-based learning in many of the online courses analyzed in this study was implemented in a similar way to traditional classrooms (e.g., cases in text delivery format, individual case studies, or case discussions). It addresses the issues of integration of diversified technological tools for pedagogical facilitation of case-based activities and developing multimedia cases in order to enhance student involvement and engagement in understanding contexts embedded in cases toward solutions from multifaceted aspects.

Keywords

Case-based learning, Online business education, Instructional design, Facilitation, Technological support

Introduction

The field of business requires multifaceted practices for real-world problems as much as or more than any other field. A business school expects that application skills and knowledge available to MBA graduates will be comparable to the skills and knowledge possessed by business professionals. Creating learning situations where knowledge can be acquired, organized, and applied, then, is a vital consideration for business educators. Case-based learning facilitates learning transfer and real-world applicability, which is the main concern in the teaching philosophy of business education.

Recent developments in advanced technology have received keen attention in the field of business education. According to Allen and Seaman (2005), more than 60 percent of schools that provide face-to-face courses have begun offering graduate courses via the web. Business schools have been aggressive leaders in this trend, and online education is highly regarded for MBA programs (Liu, Lee, Bonk, Magjuka, & Liu, 2008; Oram, 1998; Phillips, 1998). Oram (1998) indicates that technology integration with case-based learning is increasing in business education.

The integration of technology-supported instruction and case-based learning provides students with an environment to interact with a case in diversified ways and settings (Andrews, 2002). Technology support enhances the quality of case-based activities due to its capacity to immediately make available the most current issues of a case on the web, allowing students to analyze and discuss them regardless of the students' location. In case-based learning in online environments, feedback that students get from instructors and experts provides them with timely insight as to how to address or solve a particular problem or situation embedded in a case. Furthermore, instructional multimedia components — text, video, animation, narration, etc. — can help students gain a richer comprehension of the concepts and principles surrounding the case. A case, which is called a story described with rich contexts of situations, problems, knowledge, and skills to be used, also serves as support that can help to transfer learning to

various job settings. In other words, teaching and learning via case studies is powerful and will undoubtedly become richer, more authentic, and more widely used in the coming decades.

However, studies related to online learning, distance education, or other technology-supported instruction often focus on technology systems or tools, rather than on examining the underlying nature of the online environment (Bonk & Dennen, 1999). How cases can be used effectively in online environments is an area of inquiry that has not received sufficient attention from educators, considering the aforementioned plethora of instructional possibilities. It is true that there is little agreement about such fundamental issues as instructional design, facilitation for learner engagement, and technology support associated with case-based learning activities in online environments. As online programs in many educational fields — including business education — have experienced rapid growth in recent years, it is critical to examine the use of case-based learning in online environments and the obstacles and challenges that instructors and students face in their actual experiences.

Purpose of study

This study explores the perceptions of students and instructors about the current practices of case-based learning in a fast-growing online MBA program at a large state university in the Midwest. It addresses the following research questions:

1. What are students' and instructors' perceptions regarding instructional design to enhance case-based learning in online environments?
2. What are students' and instructors' perceptions regarding facilitation to enhance case-based learning in online environments?
3. What are students' and instructors' perceptions regarding technology support to enhance case-based learning in online environments?

Literature review

Case-based learning in business education

Case-based learning has been extensively used in several areas of professional education such as law, medicine, clinical health, and business as an alternative to the traditional lecture as an instructional method (Artan, 2007; Garvey, O'Sullivan & Blake, 2000; Marcus, Taylor, & Ellis, 2004; Williams, 2004). This instructional method is prevalent for teaching and learning in a business school context in particular. Instructors use business cases as the foundation of their teaching across the curriculum (Magjuka, Liu, & Lee, 2006). Case-based learning is defined as a method that

involves studying actual business situations — written as an in-depth presentation of a company, its market, and its strategic decisions — in order to improve a manager's or a student's problem-solving ability. Cases are typically used to investigate a contemporary issue in a real-life context. There are multiple issues to consider and many "correct" or viable alternatives to solve the case issues are presented (Helms, 2006, p. 68).

This definition echoes the idea that case-based learning can help students prepare to deal with the real-world problems they will face when leaving an academic environment, and ultimately, to find success within a specific business organization or profession by using these previously learned skills and experiences.

The key to case-based learning is to create cases for educational purposes and to facilitate activities associated with cases. Cases are like stories to read and explore interactively. Cases direct students toward contexts to discuss and debate issues dynamically. Williams (2004) summarizes the benefits of case use for teaching and learning, stating that it allows learners to

- apply theoretical knowledge to real school contexts
- reason critically about complex situations and recommend courses of actions
- develop self-knowledge and recognize own assumptions
- clarify personal beliefs about teaching
- compare and evaluate their own and others' perspectives

- develop the practice of reflection (p. 20)

The practical application of skills and knowledge learned in a business school is a key consideration for MBA students as well as their instructors and program designers. As a result, graduate business education has relied upon case-based learning. Many business schools have adopted the case-based learning approach as a central teaching and learning method. The features of case-based learning (e.g., applicability, contexts, etc.) fulfill the educational objectives that MBA students pursue. Students are prompted to integrate their prior experiences to analyze cases and to explore solutions through discussion, reflection, and decision making (Wang & Bonk, 2001). Case studies allow students to develop their critical and analytical reasoning skills and problem-solving processes (Merseeth, 1999). Cases that present real or hypothetical problems can prompt deep discussions, which assist students in developing solutions (Benbunan-Fich & Hiltz, 1999).

Case-based learning in online environments

While case-based learning challenges students by providing authentic experiences of business situations (Williams, 2004), case studies itself will not guarantee the efficacy of online learning processes because some effective pedagogical approaches that instructors use in their traditional classes may not be applicable for online environments.

When case-based learning is implemented online, instructors should be aware that pedagogical activities can be either limited or fostered by conditions associated with technology tools employed. Technology can offer cognitive support for student thinking by reducing working memory limitations, and help students to represent evolving ideas, concepts, and solutions. At the same time, technology can burden students since they have to manage tasks and tool functions simultaneously in the learning processes.

The review of prior studies on case-based learning in online environments implies that three aspects of online learning should be considered: (1) instructional design for case development and delivery; (2) facilitation for student engagement in online learning; and (3) technology support for effective case-based activities. From a perspective of instructional design, developing well-designed learning materials and activities is critical to effective teaching and learning. What types of cases are deemed more effective? Just how do instructors set up activities associated with cases? What degree of control do students have in different case formats and courses?

It is said that cases highlight a variety of concepts and introduce an assortment of strategies. With cases, students interpret, analyze, inquire about ideas, and solve problems. Problem-centered cases, situations, and scenarios are used to examine and clarify the complexities of practices (Rourke & Anderson, 2002). As cognitive acts occur, students begin to move from the status of a novice and gain the perspective of a professional within the field. However, the study by Marcus, Taylor, and Ellis (2004) on an online case-based learning reported findings that some students reached only a superficial level of knowledge even in a contextually rich learning environment. The less satisfactory study results remind us of the fact that the implementation of this method in itself does not ensure satisfactory learning or improvement. Rather, it stresses the significance of the design of cases and appropriate facilitation to enable students to expose students to connections between theory and practice before they actually engage in real-world experiences.

Another key to successful case-based learning is facilitation, which leads to student engagement. What determines student involvement in online learning activities? Williams (2004) points out that successful case-based learning requires instructors to employ questioning techniques and to moderate discussions through feedback and scaffolding. In online environments, dialogues and interactions are key components of a constructive environment wherein students build and negotiate their arguments and ultimately yield their final products. Action-oriented activities and discussions highlight the expanded roles and responsibilities of instructors, while often serving as the catalyst through which instructors can move from enacting the role of knowledge transmitter, to that of a learning guide or facilitator (Forman & Rymer, 1999).

A necessary ingredient for facilitation is to apply pedagogical techniques that ensure student engagement in the construction of knowledge, anchor the case to prior knowledge, and expand and transform the knowledge to real-world situations (Harrington, 1995). Such techniques as questioning, feedback, scaffolding, or guidance also assist

students in activating their meta-cognition and exploring the implications of what they endorse with peer students and instructors. The degree to which available technology is employed impacts the effectiveness and efficiency of online activities. An excellent face-to-face case study method does not always work well when implemented through technological tools. Technological support is a critical component of conducting case-based learning in online environments, while technology is the major medium through which instructions, communication, and collaboration take place. In fact, the role of technology has been expanding in both face-to-face classrooms and online environments as it plays the role of a cognitive tool that supports the creation of meaning and knowledge sharing with peers and experts (Jonassen, Peck, & Wilson, 1999). Successful online learning must create circumstances under which instructors engage students in an ongoing discussion over a case, similar to faculty-led case discussions in the classroom. Serving this purpose, tools are encouraged to be developed in a way that allows students to generate conceptual linkages and debate key points, as well as allowing for counter-cases, expert commentary, and the display of chains of reasoning (Bonk, Hara, Dennen, Malikowski, & Supplee, 2000).

Fortunately, recent advances in technology allow instructors to integrate a variety of such technological tools as asynchronous discussion forums, chat rooms, synchronous meeting tools, or multi-way conferencing (e.g., Microsoft NetMeeting, Macromedia Breeze) for the discussion and reflection of cases. Moreover, technology can support instructors in the development and presentation of cases. Since multimedia is deemed to increase the contextual understanding of a case, its use is suggested as a highly effective delivery device for cases. Cases presented with multimedia often contain an assortment of contextual facets that might be displayed through animation, video clips, text descriptions, and audio components. Of course, with all these options, presenting cases in the most compelling and efficient manner using multimedia formats is no easy task for instructors, as devising multimedia cases and converting text-based cases into different formats is demanding and time-consuming.

Data collection

This study adopted a case study to examine current practices of case-based learning in online environments. Yin (1994) defines case study as “empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident” (p. 13).

An online MBA program at a business school of a large university in the United States’ Midwest was selected for this case study. This particular program was designed for business professionals who remained active in their current employment throughout their program. While the traditional MBA program still exists at the institution, this online MBA program was established in 1999 with an enrollment of approximately a dozen or so students and saw a rapid increase in students each year thereafter. In 2006 there were more than 1,000 students taking the programs and it is now recognized as a representative online business program in terms of enrollment and diversity of the courses offered to students. Course content was newly developed or converted from traditional classroom lectures to fit online environments, and managed in ANGEL, a course management system. Course activities such as communications, announcements, and discussions were conducted online, with the exception of one residential training week.

Given the long history of the use of case-based instruction in both the traditional program and the online program, this study was designed to explore online case-based learning experiences from both student and instructor perspectives. Data collected in this study included course analyses, surveys of students, and interviews with and focus groups of instructors and students.

Course analyses

The purpose of course analysis in this study was to objectively analyze the patterns of usage of case-based learning in online courses. The present study devised an analysis framework to examine online course structure to identify how the courses utilized case-based learning in instruction. The framework consisted of several categories such as the use of technology, case delivery format, case activity, and collaboration. Twenty-seven online courses across a wide spectrum of business disciplines were selected for content analyses. The content of course websites — including student participation in course activities via asynchronous discussion boards, synchronous chat rooms, or shared workspaces — was analyzed to explore the instructional practices that had been employed in the online MBA courses. Two researchers independently conducted the course content analyses according to common themes.

Descriptive data were obtained by counting the number of occurrences based on the coding scheme. The inter-coder agreement was 81 percent, and the data coding was considered reliable.

Surveys

The survey was used to investigate student perceptions of the actual application and usefulness of case-based learning in online environments at a program level. While the content analysis coding scheme was used to analyze course design and activity structures from an objective standpoint, the survey was designed to gauge students' perceptions and attitudes regarding various aspects of online learning. The instrument contained Likert-type questions with a five-point scale (indicating 1 = strongly disagree, 5 = strongly agree) and open-ended questions. One hundred and nine second-year students who attended the first week of face-to-face gatherings in the year were invited to participate in the survey, and a total of 102 students responded to the online surveys. The detailed demographical student information revealed that 82 percent of the online MBA students were males, about 80 percent were between 26 to 40 years old, and 90 percent had taken more than seven online courses in the program. Each of the students had taken two to four different courses per quarter. The internal reliability of the survey, according to Cronbach's alpha, was reported at .91, an acceptable figure.

Interviews

Interviews of 27 faculty members and 10 students were conducted in order to obtain an in-depth understanding of the operation of online instruction within this online MBA program and of the case-based learning activities that were incorporated into it. In detail, semi-structured questions included issues such as case selection (or development), interactions with students via case studies, and effectiveness of case-based activity. Each interview took 45–75 minutes and was taped, recorded, transcribed, and coded. Transcribed interviews were subsequently classified under such categories of case-based learning as instructional design, facilitation, technology support, and other issues.

Findings

The data were analyzed into several categories based on the literature review: instructional design, facilitation, and technology support, in addition to educational value and benefits of case-based learning.

Values and benefits

One of our research findings relates to the widely held perception that MBA students and instructors value a case-based learning approach in business education. According to the survey results, 86 percent of students pointed out that case-based learning is an important instructional method ($M = 4.24$, $SD = .75$). Here, students perceived that business cases bring practical examples of what the instructors try to teach, and that course content is highly valued when instructors include opportunities for case-based study.

In terms of the benefits of a case-based learning method, about 87 percent of students pointed out that case-based learning fostered the application of newly learned concepts and skills into practices to develop critical thinking skills ($M = 4.24$, $SD = .86$). As one student noted:

Case-based learning is definitely a better way because it forces you to think and for the other ones, like, for example, the courses that were just problematic problems and answers, right? So that's very easy. If you read the textbook you can solve the problem and you don't really have to think much because you're not really thinking of how to apply the knowledge to something else.

Instructional design

Regarding students' and instructors' perceptions of the actual design of business cases and activities, the data were collected from student surveys and course analyses. According to the findings, students were satisfied with the presentation format of business cases used in their online courses ($M = 4.00$, $SD = .80$).

As a way of cross-checking student responses, the research investigated the process of case-based learning through instructor interviews. Online instructors were confident and comfortable implementing case teaching strategies in online environments since they had previously taught case-based activities in face-to-face courses. The interview analyses found that many instructors used the same case teaching materials for online instruction or slightly adapted them rather than creating entirely new materials. When they planned online case teaching, the primary aim was to create an online learning experience as similar as possible to what students had experienced in face-to-face classes. As one instructor emphasized, “(I am)...trying to make it as close to the experience that we had in class as possible, with a couple of changes.”

In terms of case selection, most instructors demonstrated considerations of how selections would cater to the nature of online learning environments. Instructors tried to select cases based on originality and real-world relevancy. They tried to update case selections to avoid re-using cases across semesters, which could lead to plagiarism in an online environment. For example, one instructor commented:

If you use public sources from very popular textbooks, there’s a lot of material out there that people can get their hands on and it’s hard to change that every semester. But in my course, these case studies are very original and I change them every semester, so it makes it harder to cheat. It makes it harder on me because I can’t keep using the same materials all the time.

In terms of case design and presentation formats, the content analyses of 27 courses revealed variations in the formats for case-based learning used in courses, depending upon the nature of specific courses and instructional purposes. For instance, cases in text delivery formats such as textbooks or text material packages were a widely used format for delivering business cases (10 courses, 37 percent).

The findings reported that five courses (19 percent) employed simulations and games as a way of enriching contexts within case studies, whereas audio or video clips were utilized in only two courses (7 percent). Activity options that provide students with an opportunity to generate cases on their own were in relatively low use (7 percent). Students showed mixed attitudes toward the use of text-based cases in online courses. Some students preferred more multi-media presentations of cases that effectively convey real-world business situations while others appreciated the efficiency of text-based case presentations. For example, two students mentioned the following:

I like the text based [cases]... I can see how they’re setting it up and where it’s going to go.

I would just like to see the business if possible because this will be just like our daily work...this [case] can be delivered the same way like live video or using the lab or whatever instead of using just plain text, that’s too primitive.

Facilitation

One of the reported concerns related to case-based learning in online environments was that students often struggle to understand how to deal with a lack of instruction (this also applies in face-to-face classrooms). This study investigated how case-based learning was coordinated and facilitated by instructors in online environments.

The findings suggest how instructors facilitate case-based learning in online environments. First of all, many instructors responded that they experienced a change in their role, and they emphasized the coach or mentor role when teaching with cases online. In effect, it was possible in online environments to monitor and support student learning with the aid of technology while, in traditional settings, in contrast, coaching was too often constrained by available time (Wang & Bonk, 2001). Guiding conceptual understanding and providing mentoring during discussion activities rather than just lecturing was more prevalent in online environments. As seen in the following quote from an instructor, encouraging discussions among students was emphasized rather than direct instruction or lectures, as often occur in face-to-face classrooms:

... They [students] associate the success of a course with how good the professor is on the platform... So coaching sounds more like what you do online... [Meanwhile] lecturing is what you do in the regular classroom.

In examining the level of interactions in online case-based learning, class discussions, self case studies, individual write-ups, role playing, and team projects stood out as the more predominant case activities employed. The findings

indicate that whole-class discussion (18 courses, 67 percent) was the most popular instructional activity with cases. On the other hand, in some courses students explored given cases individually (16 courses, 59 percent) and conducted case studies in collaborative teams (11 courses, 41 percent). The level of student engagement in group-discussions was varied, and about 15 percent of students on average were ranked as leading participants for those activities.

Moreover, managing feedback and arguments was considered another key element in the effective facilitation of online case-based learning. With whole-group discussions and team activities, peer feedback was considered critical to encourage group work. In 16 courses, students were reported to share frequent peer feedback (59 percent). Students pointed out that peer comments and advice were highly appreciated with respect to in-depth understanding. In 15 courses (56 percent), arguments and debates were encouraged with business cases. Arguments from different perspectives were also a benefit of online case-based learning. However, student choice or options for selecting different cases for discussion was relatively low (22 percent).

However, there was a limitation in exchanging feedback and comments online due to the use of asynchronous text-based communications for case analyses. Students sometimes experienced difficulty typing in their ideas fully, especially as compared to oral communications, and this obstacle often resulted in superficial discussions as shown in the remark below.

There is a little bit of difference because you have to give your feedback, the student has to give their feedback to the case online, therefore you have to type it, therefore you may be able to not type as much as you would ordinarily say and then if you type a response to a case-based question you may not get an answer to that response, therefore you may not have the ability to further the discussion. Where the message traffic may only go one or two ways, that's it; whereas if it's a face-to-face setting you may be able to say something, I'll say something back, you would say something again, and you have that exchange going on where that's definitely a limitation of the Internet.

To verify the content analyses results, student perceptions on facilitation issues were reviewed in this study. The results indicated that the level and quality of instructors' facilitation of online case-based learning was positively perceived by students. Eighty-eight percent of students responded that they were satisfied with the various interactive activities (e.g., class discussions, individual explorations, team activities, etc.) that had been designed for case studies in their online MBA courses ($M = 4.12$, $SD = .69$).

Table 1. Summary of student perceptions of case-based learning

| Item | Percentage | Mean (std.) |
|--|------------|-------------|
| Case-based learning is a critical teaching and learning technique in online courses. | 86% | 4.24 (0.75) |
| Activities designed for case-based learning are helpful in deepening my learning. | 88% | 4.12 (0.69) |
| Case-based learning experiences are critical to enhance real-world knowledge and skills. | 77% | 4.24 (0.86) |
| Technologies in online courses are effective in supporting case-based learning. | 79% | 3.84 (0.75) |
| Case-based learning is facilitated in ways to support knowledge-building. | 67% | 3.74 (0.79) |

(Percentage indicates the portion of student responses marked "agree" and "strongly agree.")

Technology support

In terms of integrating technology into pedagogy, about 79 percent of students were relatively positive about technology integration in supporting case-based learning in their online courses ($M = 3.84$, $SD = .75$). The survey and interview findings show that students and instructors expected to use more advanced technologies that might more efficiently engage the students in case-based learning activities.

An asynchronous discussion forum was still a core technological tool. Throughout the discussion forums, students brainstormed, exchanged, and elaborated on ideas that might solve a particular case situation. As alluded to previously, a common practice with discussion forums was to assign a case text for students to read before discussions and then discuss the questions posted by the instructor.

More significantly, from the course analysis, this study found that the program developed and implemented a set of proprietary pedagogical tools designed to address online case-based learning to be as effective as that of traditional classrooms. The technical functions of ordinary discussion forums were customized to ensure case-based learning activities in different ways for different instructional purposes. In the program, there were four different types of asynchronous discussion forums (the Q & A forum, round robin forum, simple forum, and role-based forum).

The previous study (Magjuka et al., 2006) explained that the main function of the Q & A forum was that students were unable to read any posts of their peers until they posted their own opinions on asynchronous discussion boards. This function allowed students to have enough time to articulate their thinking clearly. From a pedagogical perspective, this function assisted students in reflecting their learning process and building knowledge. On the other hand, the round robin forum enabled students to deal with a series of cases, and accordingly they learned how to solve problems in a sophisticated context. Also, a business law faculty member used the role-based forum to designate the roles of judge, plaintiff, and defendant, and each party placed arguments in a simulated court forum. Instructors combined forums and then strung them together over time to structure a business case analysis online for their learning goals and aspirations. The interview results of instructors and students supported different types of discussion forums that assisted in different instructional intentions.

Despite these positive findings, there remained much room for technical improvement to more effectively support online case-based learning. Instructors raised the issues of attributes of asynchronous tools such as the lack of social presence, absence of emotional cues, and high potential for misinterpretation. As shown in the quote below, one instructor noted the importance of accuracy and clarity when using online cases due to a lack of visual cues in online conversations and limited forms of instructional guidance:

The level of precision that you need in the online world is probably five or six times the level of precision that you need in the classroom, because, again, [in the classroom] you have visual cues to tell you yes or no. People, they either understand or don't understand; whereas you have to be going through much more specific detail, not even sure that they're understanding, but at least you've made the attempt to reduce any ambiguity.

It was reported that the limited capability of online technologies constrained the degree of interactive collaborations and communications in the process of case-based learning activities. Some students recognized the benefits of synchronicity via a text-based chat tool or real-time conferencing tool, which allowed them to ponder the cases and transfer their thoughts into text in real time, as shown by the following quote:

That's the only thing that really is difficult about some types of cases is how you discuss something that you would normally draw or diagram like when you're, you know, trying to motivate people to think in the same direction you are...it's great to have that face-to-face interaction because I notice it's a lot smoother when we're here in this in-residence than it is online.

Discussion

The findings of this study claim that the case-based learning approach can be as effective in online environments as in traditional face-to-face classroom settings. It reflects positive student perceptions on the practices of case-based learning in online environments. The study results imply that students learn effectively as long as online case-based learning activities are carefully designed and managed. How can we design and implement case-based learning activities successfully, considering the nature of online environments? Based on the study results, we can explore issues fundamental to the implementation of successful case-based learning in online environments.

Maximizing the use of asynchronous technological tools for case-based activities

Case-based learning comprises a student-oriented instructional approach. It is important to create an environment in which students can naturally engage in case discussions and analyze and reflect in the midst of learning processes

without pedagogical and technical barriers. The present study shows the pattern of use of technology in case-based learning in online environments. Specifically, the representative MBA program maximized attributes of asynchronous discussion forums to meet instructional goals. The study found that instructors of the program designed a variety of pedagogical activities such as questioning, debates, and role-playing to enhance case-based learning.

A set of discussion forums was designed to address these activities in an online environment to ensure the effectiveness of online learning at the same level of traditional classrooms. For instance, the role-based forum also is the place where a student can take an active role in case discussions or debates relevant to a particular topic. Role play provides an authentic learning environment where learning is situated in real-world contexts (Herrington & Oliver, 2000). With the role-based forum, students experience conflicts and confrontations similar to those which they could face in the real business world. Throughout this activity, students become familiar with how to lead arguments, make decisions, and negotiate with others for better solutions. When appropriately integrated into instructional purposes, case-based learning in online environments is as effective as it is in traditional classrooms.

Providing feedback to facilitate case-based learning activities

In the present study, we found that online instructors had actively monitored and facilitated the process of sharing multiple viewpoints and negotiating ideas during case activities through diversified instructional activities. As a result, the students reported positive learning experiences, implying that the processes of monitoring and facilitation are critical variables for determining the quality of case-based learning experiences, and instructors should transform their role to guide or facilitators from that of lecturer. This finding reflects Artan's (2007) study that interactions and quality of discussions can be influenced by instructors' intentions and facilitating skills. Further, course effectiveness improves when instructors design and facilitate case-based activities as a way to provide chances for students to reflect on their learning processes as well as on course content, as Marcus and his associates (2004) recommend.

According to the findings, peer feedback and advice were appreciated for building in-depth understanding. This result indicates that feedback from instructors and classmates is an important element that comprises successful online facilitation and promotes student learning processes. Benbunan-Fich and Hiltz (1999) reported that delayed feedback caused students to complain about the online learning process. Obviously, students in online environments have to spend more time and effort to coordinate work and combine different opinions into final products. The study claims that a critical element of successful instruction is that instructors lead students to be incisive and thorough in their case analyses by providing appropriate scaffolding to assist students in solving problems (Fitzgerald, Hollingshead, Miller, Koury, Mitchem, & Tsai, 2007). The findings indicate that the visibility of the instructor and students in the process of case activities can trigger high satisfaction with online learning.

Designing collaborative discussions to enhance case-based learning

Traditionally, case-based learning has been conducted individually by having students read problem-based scenarios to prepare for action plans and work toward solutions (Rourke & Anderson, 2002). However, the nature of case-based learning does not seek a single solution or answer to problems. It does not emphasize one correct answer; rather, it puts more weight on the process by which solutions are reached through analysis, discussion, and decision-making. An online learning environment encourages the process of developing solutions since learning experiences are constructed by conversing, synthesizing ideas, and reflecting on issues related to the presented case. Accordingly group discussions and collaboration are the most important parts of online case-based learning (Rourke & Anderson, 2002).

Not surprisingly, this study also found that individual case analyses and case essays were frequently used. The process of individual studies helps students to develop opinions on their own and to utilize personal experiences and resources for solutions. In addition to individual case studies, the findings show that collaborative work on case discussions or analyses was used extensively in most courses of this program, suggesting that technology-mediated environments might provide students with better conditions of building co-knowledge and reflection through the access of the conversations in discussion boards. Accordingly, a collaborative case-based learning approach might better fit online environments.

From an instructional design perspective, attention is brought to empirical studies, which report mixed results for case-based learning in groups. Lee's (2007) study shows that collaborative case-based learning conditions as well as traditional individual case study conditions led to improve student critical thinking. In other studies, group-based case-based learning activities in an asynchronous learning environment reach less satisfaction with the interaction process, although students produce better solutions to cases (Benbunan-Fich & Hiltz, 1999). This finding indicates that a group case-based learning activity can yield improved learning experiences for students to develop higher-order thinking, and produce more sophisticated solutions through discussions and negotiations (Salomon & Globerson, 1989), but it should be carefully designed and facilitated. For instance, as Flynn and Klein (2001) note, small group discussions can bring out better learning performance on case studies when arranged along with thorough individual preparation.

Diversifying technology to support case-based learning

Appropriate technical support and application is a crucial variable since it mediates and supports all activities and dialogues that occur in course management systems. The appropriate selection of technology and technical assistance can be a key factor in the success of online teaching and learning. In general, the study found that online instructors are skillful in integrating common course management tools such as asynchronous discussion forums in case-based learning. Although advanced technology tools are emerging in the educational field, asynchronous discussion forums were easy and favorable communication and collaboration tools for conducting case-based learning. The study also found that instructors used various types of discussion forums to meet their instructional purposes.

On the other hand, students indicate a significant desire for more interactive tools such as synchronous conferencing tools or white boards to facilitate live presentations or immediate feedback. Although these tools have been available free of charge for quite some time, few instructors took advantage of them. This is due to a lack of awareness of the existence of such tools or skills in using them. Further training on technology use is needed to further enhance an interactive case learning experience.

Interestingly, a previous study (Bonk, Hansen, Grabner, Lazar, & Mirabelli, 1998) reports that the attributes of asynchronous discussions (e.g., time delay) can prompt richer interactions and more diversity in the discussions than synchronous chatting or conference tools. This statement implies that the balanced use of asynchronous and synchronous tools is a necessity with instructional design of case learning activities rather than heavily relying upon a particular technological tool. As Rourke and Anderson (2002) reveal, instructors should maximize the unique attributes of each tool when integrating for educational purposes; for instance, emails are useful for meeting set-up and document sharing, discussion forums for idea exchange and development, and chatting or synchronous tools for brainstorming and decision making in the process of case-based learning.

Utilizing technological attributes to create richer contexts in cases

Designing activities with interesting and pedagogically sound cases that closely relate to course topics in real-world contexts is important for student online learning engagement. This study found business education experiencing a shift of its instructional circumstances from face-to-face classrooms to online environments. In this transformation, it was easily seen that the case-based learning approach was adapted in online environments, while teaching and learning materials were used in traditional formats for online environments. For instance, this study reports the wide practices of simply presenting cases in text version much the same as cases being read in textbooks in traditional classes (e.g., case scenarios in textbook package, text-based case materials, etc.). However, a written format might restrict comprehensive understanding of case situations, and presentation through multimedia elements provides a viable alternative that can increase contextual clues in cases.

Also, this study found strong tendencies for instructors to progressively integrate multimedia as a means of delivering cases in online courses, although audio/video cases and cases in multimedia were in relatively low use. Instructors often scatter instructional materials and resources that need to be integrated in a more streamlined way. As an extended step to support the use of more enriched case presentations, providing instructors and students with appropriate technology support is needed. As Orngreen (2004) points out, technical support for case development by instructors helps instructors smoothly coordinate online activities. The increase of studies on the development and

implementation of multimedia cases in educational fields is a promising sign to that end. Well-developed multimedia cases can help students to process and restore information in many ways, which triggers deep learning transfer.

In advocating the development of multimedia cases it is important to acknowledge the extra time and effort required in adopting them, in comparison to cases in text delivery formats, and the implementation of support tools has become the focus of much research. In the local context, the study found that the analyzed online MBA program had been developing an authoring tool for case-based learning titled the “Case Builder Tool,” which is similar to CaseMaker (Orngreen, 2004), designed as a supporting tool for instructors to develop and present business cases online. With Case Builder Tool, instructors could deliver cases with various multimedia elements. For example, instructors could add different components such as text, image, audio, video, and flash. Such supporting tools can help instructors to better organize their ideas to present case materials in more effective ways, while students obtain support for their individual and collaborative case analyses. Also, advanced multi-directional communication tools such as Macromedia Breeze and NetMeeting, feature desktop sharing with video and audio communications. These systems are expected to provide students with an ideal workspace to synergistically discuss cases and elaborate on solutions beyond the constraints of time and specific locations.

In summary, a key educational challenge of online courses and programs is how to develop pedagogically effective technologically mediated environments that enhance the quality of education (Benbunan-Fich & Hiltz, 1999). This study examined the actual implementation of case-based learning in an online business education. The results of the ongoing study provide implications for online instructors and designers around the globe who plan to implement case-based learning in professional development courses and programs within higher education. Clearly, those in other professional schools (e.g., law, education, business, engineering, and medicine, etc.) will be interested in how to effectively embed the strategies of case-based learning in their online courses. The key results can be highlighted as follows:

- Case-based learning is a method widely used in online business education as well as in traditional classroom settings.
- Students and instructors perceived that case-based learning is a favorable method for online environments to foster application of newly learned knowledge into practice.
- Facilitation and timing feedback are key pedagogical techniques to enhance case-based learning in online environments.
- Whole case discussions and group discussions are widely used in online environments.
- Asynchronous discussion forums still play a key role in case discussions, although newly advanced technology is also available.
- Technology tools customized to meet educational purposes and learning activities enhance the quality of online learning activities
- Cases in text formats are still the most widely used means of case-based learning even in online learning environments. Diversifying case delivery formats is a way to create richer contexts, and multimedia cases can be one of the options.

It is recommended that online instructors, instructional designers, and support staff acknowledge that the success of online business courses depends not on merely introducing advanced technology tools or systems by themselves but also on integrating appropriate uses of pedagogy in business contexts. This study suggests that instructors and students need to have more guidance both pedagogically and technologically to make a successful transition to online learning environments. In the end, this study provides a starting point for understanding the status of case-based learning in an online MBA program.

Recommendations and limitations

Although case-based learning is already a widely used method in business schools, how to best utilize online technology in case-based learning is an issue that must continue to be addressed by educators and researchers. While there is a substantial body of research related to case-based learning in online environments, few research efforts have specifically established guidelines, caveats, and other knowledge deemed vital for building and designing case-based learning in online environments.

This study examined the current practices of case-based learning in online business education from three aspects: (1) instructional design, (2) facilitation, and (3) technology support. It reconfirms the positive roles of case-based learning in online business education. This study demonstrates that under authentic learning environments in which learning is situated in real business contexts, case-based learning is a core pedagogical method to create extensive applications of knowledge and skills across all business disciplines. To bring out extensive learning transfer through online case-based learning, a creative design of instructional activities and comprehensive facilitation is critical (Garvey et al., 2000). There are several recommendations and limitations for better designing case-based learning activities.

First, there is a need to provide detailed instructional guidelines regarding how to support student learning over the course of working with a case. Students who have never experienced case-based learning before can feel uncertain about the specific skills and knowledge they are supposed to acquire and how they are supposed to learn; ultimately, they often feel frustrated. Further, case-based learning in online environments can be a burden to conduct for students who are accustomed to instructor-oriented lectures in classroom settings. Students should be familiar with case-based learning procedures and functions of technological tools that are used for online learning activities. Accordingly, detailed instruction and elaborated coordination of case-based activities can assist in reducing ambiguity and confusion in learning processes.

Second, effective instruction provides students with opportunities for planning and monitoring their learning journeys. It is beneficial for students to reflect on the contents and processes of their activities while facing the challenge of solving cases (Marcus, Taylor, & Ellis, 2004). Reflection can assist students in making decisions based on constantly changing sources of information. Instructors can guide student activities by offering questions that trigger deeper thought about cases and providing students with comments that can stimulate reflection.

Third, effective case analyses are followed by the synthesis of learned concepts and knowledge. Relative learning resources and supplemental information are essential to enrich students in their practices of analyzing, filtering, and integrating information to develop solutions. For instance, hyperlinks and information embedded in the learning management system or posted on the web are highly useful to expand students' learning experiences.

Despite its helpful implications, this study has its own limitations. As a case study, the participants were limited to one online MBA program, and only a small sample of participants participated in the interviews. As a result, caution should be exercised when making generalizations of the findings presented here and projecting them onto other online programs or disciplines. However, this examination is expected to expand the lessons learned, with implications for those who hope to introduce case-based learning methods into the curriculum for their online business programs, despite the fact that the present study focuses on one representative online MBA program. In summary, it is expected that the findings and recommendations raised in this study provide highly valuable information and insight to assist online educators in designing successful and engaging case-based online learning experiences.

This study did not address the impact of case-based learning on actual learning outcomes or performance in online environments. The follow-up study needs to investigate learning improvement in comparing several conditions: traditional case-based learning versus online case-based learning, or individual case-based learning versus collaborative case-based learning.

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Construction and Evaluation of Animated Teachable Agents

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ABSTRACT

This article describes the design decisions, technical approach, and evaluation of the animation and interface components for an agent-based system that allows learners to learn by teaching. Students learn by teaching an animated agent using a visual representation. The agent can answer questions about what she has been taught and take quizzes. The agent's performance provides students feedback and motivation to learn, and the overall interaction helps students learn for themselves. The teachable agent uses speech and animation to communicate with the student, and sometimes expresses emotion through her spoken dialog and facial expressions. The technical approach is novel in that it provides a system for creating and customizing an animated agent and associated content in a fast and efficient manner that does not require specialized modeling or animation skills. We evaluate both our interface design and the effects of animated agent on students in a U.S. public school aged 9-11. Results show that the both the new interface and the presence of an animated agent promote positive learning experiences.

Keywords

Teachable agent, Learning environment, Pedagogical agent, Animated agent

Introduction

This paper describes the educational technology and interface behind a model-free, customizable animated agent and its evaluation in a classroom setting for learners aged 9-11 (U.S. fifth grade). The agent, called a **teachable agent**, is a component of a learning system that implements the principles of learning by teaching. It is well-documented in the educational literature that the process of teaching others can be a powerful method of learning, e.g., (Armistead 1983). Studies have shown that people who prepared to teach others to take a quiz on a passage learned the passage better than those who prepared to take the quiz themselves (Bargh and Schul 1980). Similarly, literature on tutoring suggests that tutors benefit as much from tutoring as their tutees (Graesser et al. 1995; Chi et al. 2001). Biswas et al. (2001) report that students preparing to teach stated that the responsibility of teaching forced them to a deeper understanding of the material; other students focused on the importance of having a clear conceptual organization of the materials.

A teachable agent (TA) environment (Biswas et al. 2005; Nichols 1994; Ramirez-Uresti and du Boulay 2004) is one where learners explicitly teach and directly receive feedback about their teaching through interactions with a computer agent. In our TA system, called Betty's Brain, students learn by teaching a computer agent called Betty to solve problems and answer questions in a variety of scientific domains using graphical cause and effect structures. Unlike previous TA work (e.g., (Michie et al. 1989; Nichols 1994; Ramirez-Uresti and du Boulay 2004)), Betty has no a priori knowledge, only an ability to reason (Davis et al. 2003; Leelawong and Biswas 2008; Viswanath et al. 2004). The agent is explicitly taught knowledge by learners, who are learning and organizing their own knowledge as they teach. Teachable agents are thus similar to pedagogical agents (Baylor and Ryu 2003; Baylor 2005; Graesser et al. 1995; Towns et al. 1998) in the sense that the agent helps create a positive learning experience and facilitates meaningful interaction between the computer and the learner (as shown by, for example, (Craig et al. 2002; Moreno and Mayer 2000; Lester et al. 1999)). However, the pedagogical agents cited above are primarily demonstrative and active tutors of knowledge, whereas a teachable agent positions itself as a learner. The effectiveness of the teachable agent environment in producing learning-related outcomes has been reported in (Davis et al. 2003; Biswas et al. 2005; Tan et al. 2006; Leelawong and Biswas 2008).

The particular goals of this article are twofold. First, we present an analysis of the user interface of the teachable agent system as it relates to its effectiveness in promoting learning related outcomes. Part of the user interface is an animated videorealistic character that serves as the teachable agent. We present the novel technical machinery that allows the construction of such an agent. We use the term videorealistic to mean that the agent is not cartoon-like (a

cartoon image was used in earlier studies, e.g., (Biswas et al. 2005; Davis et al. 2003)), but looks closer to a photograph of a person. The structure of our machinery does not use an underlying graphical model, as is commonly used, e.g., (Cole et al. 1999; Elliott et al. 1999), but is based only on image data. This approach can be used to author content easily and customize the teachable agent system as desired. Authoring animation and customizing the appearance and emotional expressions of the agent is typically an expensive process, one which our method seeks to make easier. The goal of this approach is thus to create an animated agent that can reliably convey expressions and emotions that we believe are conducive to learning, in a particular environment, and for a particular class of learners. Animated teachable agents have the potential to affect learning by providing interactions that enhance the constructivist learning experience and increasing motivation through recognized social interactions (Baylor et al. 2004).

More particularly, we explicate these goals and answer two specific questions: (a) does the presence of an animated agent in a learning system create a more positive learning experience than the learning system without the animation; and (b) how does the representation of the agent (its appearance, style of emotion, and animated content) affect the learning experience. While prior studies have asked these questions for college-age learners (e.g., (Ryu and Baylor 2005)), less attention has been devoted to these issues for elementary and middle school children. This factor is critical, since affordances of a system that benefit advanced learners may not create a positive experience for 9-11 year olds (Viswanath et al. 2004). Quick customizability and a model-free representation in the animation engine of the underlying agent can allow us to assess these conditions better. This paper addresses only the first question above, and does so in the context of the Betty's Brain system.

This paper discusses studies where students teach their agent about the domain of pond and river ecosystems. In Tennessee, students in public schools age 9-11 learn about ecosystems as part of their science curriculum, including the major levels of biological classification, the food chain, photosynthesis, and the waste cycle. The aim of the Betty's Brain system is to aid students in learning about entities and interdependence in such ecosystems by studying the causal relationship between pairs of entities, e.g., fish breathe dissolved oxygen, and how these changes propagate to other entities to establish chains of events. We describe these items in greater detail below.

Background

An automated learning by teaching system requires a representation scheme for learners to create their knowledge structure as a part of the teaching process. Since the primary users are students aged 9-12 (5th and 6th grade students in U.S. "middleschools") who are solving complex problems, this representation has to be intuitive but sufficiently expressive to help these students create, organize, and analyze their problem solving ideas. We adapted and extended a widely accepted technique for constructing knowledge, a concept map (Novak 1996; Spiro and Jehng 1990), as our visual representation scheme for the teaching task.

Concept maps provide a mechanism for structuring and organizing knowledge into hierarchies, and allow the analysis of phenomena such as cause-effect relations (Leelawong et al. 2001; Kinchin et al. 2000; Stoyanov and Kommers 1999; Novak 1998; Novak 1996). Moreover, our studies have shown that students relate to the intelligent software agents, particularly because the agents use the concept map to generate answers to questions, and explain how they derived their answers (Biswas et al. 2005; Leelawong and Biswas 2008). In all of our studies, students have not had problems using the concept map interface. Therefore, concept maps provide an excellent representation that helps students teach their agent and monitor their learning through the teaching process.

The Concept Map

A concept map is a collection of concepts and the relationships between these concepts that collectively represents domain knowledge (Novak 1996). A partial concept map in the domain of river ecosystems is shown in Figure 1. The labeled boxes correspond to entities (the labels are entity names), and the labeled links correspond to relations between the entities. The arrow indicates the direction of the relation, and its name appears by the arrow. The parenthesized phrase indicates the relation type.

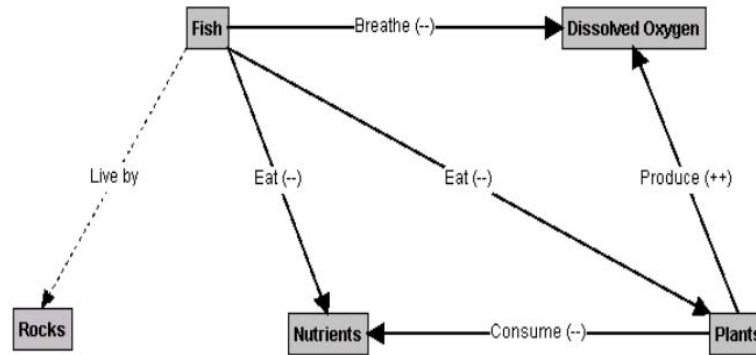


Figure 1: Example concept map for a river ecosystem

In our environment, concepts are entities that are of interest in the domain of study. Common entities in a river ecosystem are fish, plants, bacteria, dissolved oxygen, carbon dioxide, algae, and waste. Relations are unidirectional, binary links connecting two entities. They help to categorize groups of objects or express causal relations between them.

In the current implementation of this domain knowledge, learners can use three kinds of relations to build a concept map: (i) cause-effect, (ii) descriptive, and (iii) type-of. The primary relation learners use to describe relations between entities is the cause-effect relation, such as “Fish eat Plants” and “Plants produce Dissolved oxygen”. The causal relations are further qualified by increase (‘++’) and decrease (‘-’) labels. For example, “eat” implies a decrease relation, and “produce” implies an increase. Therefore, an introduction of more fish into the ecosystem causes a decrease in plants, while an increase in plants causes an increase in dissolved oxygen.

The descriptive link represents a broader relation between two entities, but the change in one entity does not cause a change in the other entity. An example is the relation “Fish live by Rocks”. The “live by” relation is descriptive, because an increase or decrease in fish does not directly change the amount of rocks. More complex forms of the “descriptive” relation, e.g., “Plants need Sunlight to produce Dissolved Oxygen” are conditional causal relations and have been implemented in some versions of the system, but not in the one discussed in this article.

Type-of relations let learners establish class structures to organize the domain knowledge. Consider an example where learners deal with a variety of fish, such as trout, bass, blue gill, and catfish. All of these fish types breathe dissolved oxygen and eat plants. To simplify the knowledge construction process, learners can first create the entity “Fish”, and express the “Fish eat Plants” and “Fish breathe Dissolved Oxygen” relations. Then, they can create individual fish entities, such as “trout” and “bass”, and link them to the “Fish” entity using “type-of” links. All relations associated with the entity “Fish” are inherited by these individual types unless they are over-ridden by more specific links (Russell and Norvig 1995).

Description of Betty’s Brain

This section presents the user interface as described by (Davis et al. 2003), which did not contain an animated agent. The next section presents an analysis evaluating the user interface of the teachable agent system. It analyzes the various trade-offs involved in determining which features should be present in the user interface and how the various components should be designed, particularly with the idea of adding animation. Some of these refinements were suggested by (Viswanath et al. 2004) in a preliminary study on the efficacy of the user interface. All refinements and changes will be evaluated through studies on public school students age 9-11 (U.S. fifth grade), a target audience for this system.

Figure 2 illustrates the Betty’s Brain interface. The system possesses multimedia capabilities. Betty appears as a cartoon face and interacts with the students using speech, text, and an animated concept map to explain her reasoning. Students use a graphical drag and drop interface to create and modify their concept maps. When queried, Betty can provide answers, and explanations for how she derives her answers, and simultaneously speak and

illustrate the derivation process on the concept map by animation. The interface of Betty's Brain is implemented in Java with Java Swing components. In the sections below, we describe the software's three modes: *TEACH*, *QUERY* and *QUIZ* that reflect generic teaching activities.

TEACH Betty: As mentioned previously, students teach Betty using a concept map interface. Figure 1 displays an example of a concept map used to teach Betty about the river ecosystem. The map shown is not complete.

QUERY Betty: Students are able to query Betty about what they have taught her. Betty has templates for two types of queries:

1. What will happen to concept A when we increase/decrease concept B?
2. Tell me what you know about concept A.

To answer questions in the form above, Betty uses a simple chaining procedure to deduce the relationship between a set of connected concepts by propagating the effects of the change and resolving loops in the concept map through a process described in Biswas et al. (2005). After Betty answers a question, the student can then ask her to explain how she derived her answer. Betty verbally explains her answer while simultaneously animating the concept map.

QUIZ Betty: During the quiz phase, students observe Betty's responses to a set of pre-scripted questions. A mentor agent informs Betty (and the student) if Betty's answers are right or wrong. The mentor also gives hints for each question to help the student correct errors in the concept map they have created. The system implements three levels of hinting, from suggesting that the student read a section of the resource materials to directly telling the student how to correct the concept or link in the concept map.

The initial phase, much like a real teaching task (preparing to teach) consists of the students learning for themselves by reading resources provided to them and attempting to organize what they are learning so they can teach Betty using the concept map representation. During this phase, there is little response from Betty but use of the map building interface is high. Therefore, it is important that the interface be easy-to-use because learners are struggling to convey domain knowledge in concept map form and are not experiencing any interaction with the agent that supports the learning activity or provides motivation. Once the learner is past the initial teaching phase, the level of interactions with the agent increase significantly through the query, explanation, and quiz mechanisms. Our studies have shown that the learners are motivated by the responsibilities of continuing to teach Betty so she can do well in her quizzes, so they continue to refine their maps, ask her more queries, and get her to take quizzes to check how well she is doing (Biswas et al. 2005; Leelawong and Biswas 2008). Betty's quiz scores, and by extension the learner's knowledge improves with time, and, in past studies, a number of students succeeded in getting Betty to get a perfect score on her quizzes in 5-6 45 minute sessions (Tan et al. 2006).

Animation for Betty's Brain

Given the importance of initial map creation and subsequent interactions with Betty in aiding and motivating student learning, we decided to make Betty a more powerful and realistic animated agent, which she was not in the prior studies. Animation allows us to explore emotive behaviors that may further engage the learner, as has been shown and associated with improved learning outcomes (Baylor and Ryu 2003; Elliott et al. 1999; Towns et al. 1998). As mentioned previously, our goal is to create an agent that is easily customizable, which may in the future allow us to explore more fully the psychometric structure of a teachable agent as has been done for a pedagogical agent (Ryu and Baylor 2005). In addition to emotional expressions, we design the teachable agent to speak and animate synchronously as she speaks. We use synthesized speech, although studies have shown that learners may be affected by how real the agent's voice is (Forbes-Riley et al. 2006; Atkinson et al. 2005).

The technical goal is to synthesize an easily realizable, controllable videorealistic character that includes a speech engine. The character should resemble a human, have lip movements synchronized with speech, and demonstrate different facial expressions that are related to their performance on the system. For example, Betty should appear happy if she does well on a quiz or her quiz scores improve. Similarly, she should have a sad expression if she has not done well, and if her quiz scores go down. There have been several systems that produce videorealistic animation

(Ezzat et al. 2002; Bregler et al. 1997; Blanz et al. 2003). These systems are quite powerful; what distinguishes ours is the speed with which a videorealistic model can be produced. We were willing to sacrifice some quality and power to achieve this speed. For example, (Ezzat et al. 2002) report that the process required to produce a speech animation module is on the order of several days in a semi-automatic manner. In contrast, our method takes only a few hours to produce a working module, with no more manual intervention than prior systems. This fast production time is desirable in various applications such as teachable and pedagogical agents, where, for example, the agent may be customized to the application as it is deployed.

Technical Approach

The key idea of this work is the use of nonlinear dimensionality reduction techniques to create a fast parameterization of the corpus of video footage, and then to play the footage back in a novel manner as directed by the circumstances of the teachable agent system, on a frame-by-frame basis. Dimensionality reduction has been a component of several animation techniques. The traditional technique is linear dimensionality reduction using Principle Component Analysis (PCA) (Jolliffe 1986), a technique that generates mean data and eigenvectors that span the principle shape variations in the data space. PCA generates a k -dimensional subspace that optimally approximates a zero-mean data set in a least squares sense. Multidimensional scaling (MDS) (Kruskal and Wish 1978) represent a set of alternative techniques that find an embedding that preserves the pairwise distances. It is equivalent to PCA when those distances are Euclidean. PCA has been used by (Guenther et al. 1998) as a component of their facial animation system, and more recently by (Safonova et al. 2004) to represent motions in a lower dimensional space for dynamic optimization.

We have found that linear techniques (PCA, classical MDS) do not provide adequate dimensionality reduction to solve the problems we discuss below. This inadequacy manifests itself by requiring a high dimension to reduce standard error heuristics to reasonable values, and interpolation or blending methods not producing acceptable results when used in these spaces. In other words, even when preserving the computational burden of high dimensionality, simple blending gave unpleasant visual artifacts. We therefore examined nonlinear techniques, which can capture the dimensionality and geometric structure of a larger class of manifolds. Kovar and Gleicher (2004) use similar ideas in their system to build new animation from large datasets. Grochow et al. (2004) do style-based posing of articulated figures using Gaussian Process models. These models, while elegant, in our experience have a tendency to get trapped in local minima and thus require expensive optimization machinery.

The technique employed in this paper for manifold-based nonlinear dimensionality reduction is Isomap (Tenenbaum et al. 2000). Locally Linear Embeddings (LLEs) (Roweis and Saul 2000) are a related technique. Both methods use local neighborhoods of nearby data to find a low-dimensional manifold embedded in a high-dimensional space. There is a large literature on nonlinear dimensionality reduction, and alternative techniques are available, e.g., (Hastie and Stuetzle 1989; Brand 2002). Isomap is a polynomial-time algorithm that reaches a global minimum for the data. An extension of the Isomap technique to incorporate temporal structure into the data was developed by (Jenkins and Matarić 2003) and is called ST-Isomap. They focus on synthesizing humanoid motions from a motion database by automatically learning motion vocabularies.

In our work, we use Isomap to parameterize a corpus of video data, then walk the computed manifold based on the output of a text-to-speech system to synthesize speech. Isomap works by computing an embedding of the data within the original data space, giving a one-to-one correspondence between the original data and the embedded data. Given a data set living in a high-dimensional space X with distance function D_x both techniques pursue a three-step algorithm to compute the embedding, as follows:

1. Compute local neighborhoods based on the distances $D_x(i, j)$ between all pairs of points i and j in the input space X . These local neighborhoods are clusters of points for which the input space metric closely approximates the geodesic distance, e.g., the distance along the manifold. Next we define a neighborhood graph G by connecting i to j if it is one of the K nearest neighbors of j . The edge length is set to $D_x(i, j)$.
2. Globally connect the neighborhood graph G by estimating the geodesic distances between all pairs of points. This distance matrix, D_G is determined by computing the shortest paths between all pairs of points in G using Floyd's algorithm (Sedgewick 2002).
3. Embed the data into a lower dimensional space using MDS.

Isomap will find a good lower dimensional manifold as long as the data set is sufficiently dense and can form a single connected component. The computations in Isomap guarantee a global minimum, and the dimensionality of the embedding can be estimated by examining the residual variance of the output of the MDS stage of the algorithm. A key to finding a good embedding is finding a good distance metric with which to compute the local neighborhoods (Seward and Bodenheimer 2005). For this work we simply use the vector difference of two frames as our metric.

An Enhanced Interface for the Teachable Agents System

A previous study conducted in the Nashville Metropolitan school system indicated that the user interface needed improvement (Davis et al. 2003; Biswas et al. 2005). On the one hand, students attributed an independent identity to their agent, Betty, though they knew she was just a computer program because she could answer questions and explain her answers with the concept maps they taught her, sometimes better than they could (?). But it took students quite some time to learn how to use the concept mapping interface, and the query and quiz functions in an effective way, which made them less focused on learning and teaching domain knowledge. Other shortcomings that students pointed out in exit interviews were that Betty, as a good student, should be more interactive, e.g., “to react to what she was taught” or “do some sort of game or something and make it more interactive.” The previous Betty character was quite passive, and only responded when the student asked her questions or asked her to take a quiz. Reflecting on the study results and student feedback, we decided that Betty needed to demonstrate more qualities of good human students in a more convincing manner. At the same time, we redesigned the interface to make it more self-explanatory so that the students found it intuitive and easy to use with minimal training.

Figure 3 shows our enhanced interface for Betty’s Brain that makes the system easier to use for novices. These changes are implemented as two inter-related factors: (i) visual, which includes aesthetic appearance, look-and-feel, and the presence of a videorealistic character, and (ii) cognitive, which is directed to functionality, and information representation and interpretation of the features provided by the interface.

Causal links form an important part of the concept map structure. The original interface differentiated between the increasing and decreasing effects by using the symbols (++) and (–), respectively. This representation was confusing to our young users, therefore, we decided to use colors to more explicitly represent the semantics of the causal links: red is used to represent a decreasing effect, and green represents an increasing effect. We kept the symbols (++) and (–) along with the colors to provide redundant but very useful information. The sign information should provide help to users who are color-blind.

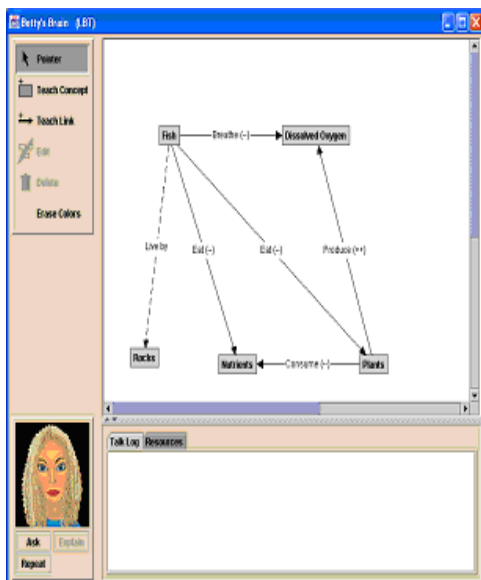


Figure 2: Original Betty’s Brain Interface

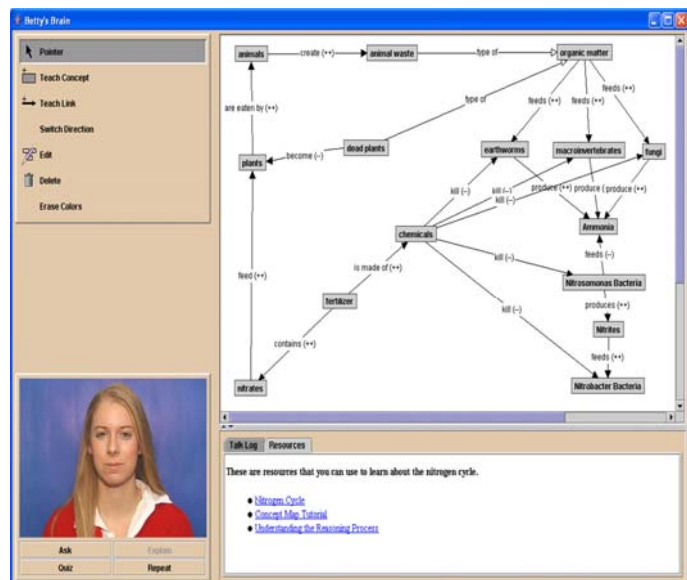


Figure 3: Enhanced Betty’s Brain Interface

Data from the prior study indicated that some of the common errors students made were (i) the incorrect representation of the effect of a causal link (creating a causal link with increasing effect instead of a decreasing effect), and (ii) specifying the direction of the arrow incorrectly. When students got into the monitoring phase using the quiz or by asking queries, they found it hard to pin point these errors, and even when they did, they found it frustrating to correct them using the original interface (Davis et al. 2003; Biswas et al. 2005). For example, if students had mistakenly created a link that indicated “Earthworms produce ammonia causing ammonia to decrease” changing the relation of the link from “decrease” to “increase” involved selecting the link by clicking on it, deleting it, and then recreating a causal link of the appropriate type from “Earthworm” to “Ammonia.”

In the new interface, two buttons — “Switch Trend” and “Switch Direction” — were added to help students easily rectify these common mistakes with a single click. For example, to change a trend in the relation “Animals eat plants causing plants to increase”, the student would select the link and click on the “Switch Trend” button to rectify the mistake. The “Switch Direction” button changes the direction of the link selected.

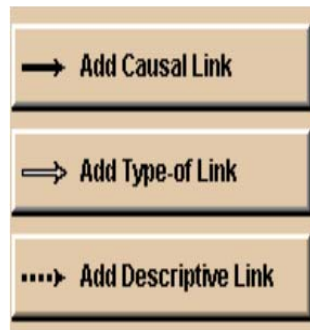


Figure 4: Original Individual Buttons

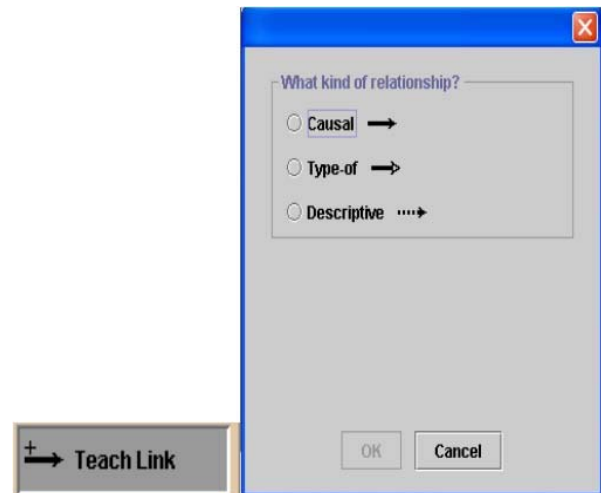


Figure 5: Pop-up window displayed in the new interface when the “Teach Link” button is clicked.”

An issue in the introduction of these buttons was the concern that students might use them to employ a “quiz-edit-quiz” strategy (Wagster et al. 2007). Since students found it hard to pinpoint the error, especially for answers that involved longer chains of reasoning, making it easier to switch trends or directions would lead to students developing a strategy to “game” the system, i.e., make repeated changes to the current concept map, and after ever change take the quiz to see if previously incorrect answers were now correct. This strategy is clearly undesirable – it implies a “guess and check” approach to learning instead of learning with understanding. To guard against it, we added a pattern tracking agent to detect this pattern of activity by the students. When this is detected, Betty balks at taking a quiz, and indicates to the student that she feels that she “has not learned anything new, and, therefore, (she) may not do well on the quiz.” She suggests to the student that they read the resources, teach her more, and check if she has learned by querying her before sending her to take the quiz again. This guided feedback has been shown to be more effective in promoting a positive learning experience than simply allowing the “quiz-edit-quiz” strategy (Tan et al. 2006; Wagster et al. 2007). The original interface provided three different buttons for adding a link in the concept map, corresponding to the three different types of links. Though currently screen space is not an issue, in the future when new features are added there may be space constraints. Therefore, these three buttons were replaced with just one, labeled “Teach Link”, in the new interface. On clicking this button, a window pops up as shown in Figure 5. The users can select from this window which type of link they want to create.

Animated Agent Construction

Our method is to record a sequence of video with a subject speaking visemes, facial images corresponding to phonemes; in English there are 23 visemes. Additionally, the subject records several facial expressions such as a

happy, sad, frustrated, and bored. These emotions represent states that we believed applied important affect: happy when performing well, sad when performing poorly, bored and frustrated when it seemed the students actions were not constructive. This sequence of video is typically about 40 seconds long. Individual frames of the 23 visemes are then manually selected (Figure 6, from left to right, the “v” sound in river, the vowel sound in “ear,” and the vowel sound in “too.”). This process takes about 15 minutes. To make the data set more dense, a random number of images from the recorded sequence are selected. We experimented with several values and found that 200 extra frames works well. The resulting data set is then downsampled by a factor of 8 to 90 by 60. Isomap is applied to the downsampled data set and a dimensionality for the embedding is selected. This part of the process takes about two hours. In our experience, a three-dimensional embedding with a neighborhood size of three works well. At this point we can traverse the graph, and, using the high-resolution images, create animation. The Isomap graph in two dimensions and the residual variances (error for dimensionality reduction) are shown in Figure 7. In this figure, the individual frames of video are denoted by the circles, and the graph edges represent the connections between frames that are similar. Each circle represents a frame of video, reduced from its original high dimension (5400) to two dimensions (in the Figure, three dimensions internally). This reduction in dimension comes at the cost of the error shown as the residual variance in the Figure. Thus, the error of the embedding from its original high dimension (5400) to dimensions of 10 and fewer are shown in graph on the right. Selecting the “knee” at dimension three works well for all examples we have tried. The graph of frames, hence of speech, thus constructed is then used in the animation as described below.

In our first example, the goal is to use Isomap to create a speaking, animated character whose lip movements are synchronized with speech, and whose facial expressions display some basic emotions that are linked to learning tasks. In addition to the 23 visemes, we captured facial images portraying six emotional states such as sad, angry, and confused. We segmented the image into two parts. When the character was speaking, the emotional state of the character was conveyed primarily by the character’s face, neck, and shoulders. When the character was not speaking, the mouth depicted the emotional state of the character. To accomplish this two stage behavior (speaking and showing emotion), we had to do additional processing.

Although the subject was instructed only to move their lips in the training video, some translation and rotation of the head, neck, and shoulders did occur. To stitch the animation of the mouth onto a foreground image, the video frames had to be aligned so that the character was in the same position. To align these images, contour points of the subject’s silhouette in each frame were extracted, and then used to register each successive frame to the first frame using an iterative closest point method (Besl and McKay 1992). The alignment process took about two hours. Once the set was aligned, the mask used for the mouth images was created by hand drawing the outline of the mouth and jaw on a single frame of the aligned images. The seams of the mouth images were blended with the foreground image. Figure 8 shows this process.

The mouth movements are controlled by a text-to-speech engine so that sound and animation are synchronized. When a word is to be spoken, our software breaks the word into visemes. Additionally, the character’s expression is controlled by an emotional state variable. The emotional state variable is controlled by an algorithm that assesses several factors in the state of the learning process. As mentioned above, Betty can have an emotional state of unhappy, for example, if she does not do well on a quiz; she can be frustrated if she is not taught a sufficient amount between tests. And she is happy, when she passes a quiz.

When these states change, a transition to a new expression must be made. Both of these changes can occur simultaneously using the blending method described above. The emotional state traverses the graph on one path, while the speech part traverses the graph along another. The blending algorithm stitches the moving mouth into the emotional image of the state. Our graph traversal is done as follows. To transition between two visemes, we find the midpoint of a straight line in the embedding space that connects the two visemes. We then find the closest image to that midpoint in the embedded space. Due to the rate at which the character speaks, the transition between visemes can only be a single image and maintain synchronization with the audio (Figure 9). Nonetheless, it seems realistic. If the character’s mood changes, the foreground image will transition to a new mood by approximating the straight line connecting the two images. When transitioning from emotional states, interpolation images are selected along uniformly spaced intervals of the connecting line segment. As a result of these transitions found by the Isomap algorithm, we have succeeded in creating a videorealistic animated model that can speak any word in real time based on its visemes.



Figure 6: Three video image each representing a viseme

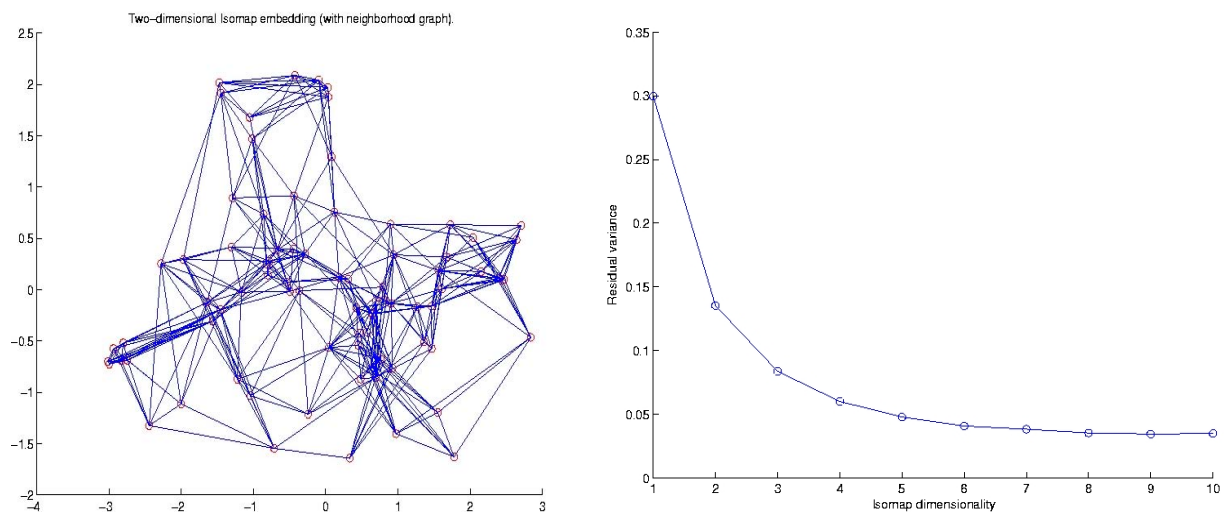


Figure 7: The Isomap embedding (left) and residual variance (right) for first example. For purposes of illustration, the figure on the left shows the graph of shortest path distances between images of facial expressions, reduced in dimension to a two-dimensional space. The residual variances shows the error of the embedding process from its high dimension to its low dimension. The “knee” of the curve is three dimensions.



Figure 8: Emotional expression with silhouette (left), masked viseme (middle), and blended image (right)



Figure 9: The middle image is the interpolating frame for the left and right images

A second character is shown in Figure 9. A subject is again recorded speaking. However, for this character, we do not align our dataset, nor do we change the emotional state of the character. We simply extract the visemes and additional frames that are used for transitions, and omit the registration steps. The result is a videorealistic character with natural head and shoulders movement. The character shown in Figure 9 is a prototype for a mentor agent and is included here for comparison. It was not used in the evaluation studies discussed next.

Evaluation

Interface Enhancements without Animation

To evaluate the effectiveness of our changes, we conducted a usability study on the interface. Study participants were 48 high achieving students aged 9-11 (U.S. fifth-grade) from an urban public school located in Metro Nashville. High achieving students were selected to avoid confounds associated with poor reading ability. The students were part of a larger study that investigated the effects of self-regulated learning using Betty's Brain, and were familiar with working on Betty's Brain by the time this study was conducted (Leelawong and Biswas 2008). Hence no training in working with the interfaces was needed, though the new features of the interfaces were shown and explained to them. The user study had three phases: introduction, testing, and questionnaire sections.

In the testing phase, the students were asked to correct a relatively simple concept map that had two errors (the complexity of the concept map is similar to that shown in Figure 2). Half the students worked on the new interface first while the other half worked on the old interface first. Then they switched the interfaces they were working on, now carrying out the tasks on a different concept map. The order of the concept maps was also switched to remove any bias that could possibly be created by the different maps used.

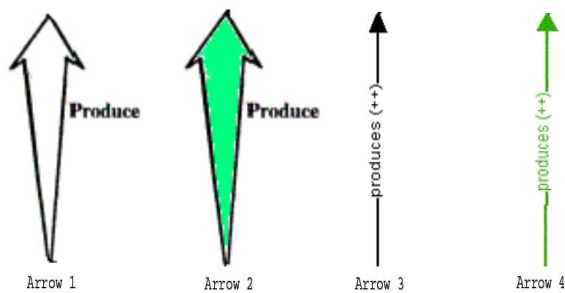


Figure 10: The four options to represent a causal link with increasing effect

| | High Preference to Lowest | | | |
|---------|---------------------------|----|----|----|
| Arrow 1 | 2 | 10 | 15 | 21 |
| Arrow 2 | 20 | 16 | 18 | 4 |
| Arrow 3 | 2 | 8 | 16 | 22 |
| Arrow 4 | 24 | 14 | 9 | 1 |

Table 1: Student's feedback in the questionnaire section regarding causal links

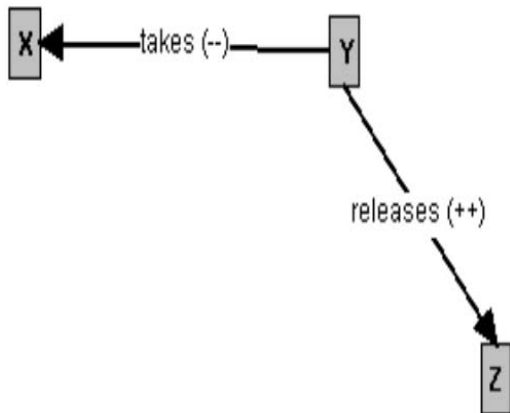


Figure 11: If Y decreases, what happens to X and Z?

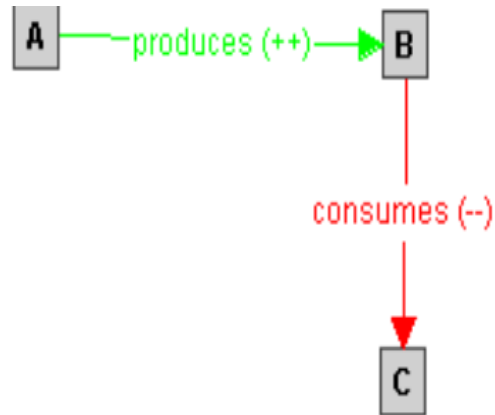


Figure 12: If A decreases, what happens to B and C?

Finally users answered a paper questionnaire. In the questionnaire, they were asked to compare features in the two interfaces. Also, to find out how color affects the understandability, the students were shown concept maps outside of the river ecosystem domain, and they were asked to answer questions on them. Part of the questionnaire asked for preferences only, and did not evaluate a learning related outcome associated with those preferences.

Discussion of Results

Log files were generated for each section of the test tracking every action of the user along with a time stamp. These timings were used for comparing the two interfaces. They were analyzed using a two-way ANOVA to control the effect of the ordering of the interfaces.

When correcting a concept map, learners were faster using the new interface (mean 66.9s) than using the old (mean 124.41s). These results are statistically significant ($F = 14.92$, $MS = 72680$, $p < .01$). These values imply that the students found it easier to go about their teaching and learning activities using the redesigned user interface. The effect of the ordering of the interfaces on their time to perform activities was not significant. This result is reasonable since, as mentioned before, the users were experienced with the software and thus the order in which the interfaces were presented to them did not have any significant effect. Neither were interaction effects significant.

In the questionnaire, the users were asked to mark their preference regarding adding the links — whether they liked to have separate buttons for each link or they liked the pop-up style. 33 out of the 48 users preferred the pop-up style, whereas the other 15 preferred to have separate buttons. This preference is statistically significant ($\chi^2 = 6.75$, $p < .01$). Students were also asked which style of arrow (shown in Figure 10) they preferred to represent causal links for increasing and decreasing effects. They were asked to rate them according to order of preference. Table 1 shows results of this ranking for the four different options shown in Figure 10. As can be seen from this table, the users felt that the arrows used in the new interface (arrow 4) was better than the format used in the previous interface (arrow 3). The positive effect of color is clearly substantiated by their choice of arrow 2 over arrow 1.

However, other related items on the questionnaire presented a different picture. The questionnaire had two concept maps - one using normal block arrows (as in the old interface) and another, which used colored arrows (as in the new interface). The students were asked to answer two simple questions of the type “If A increases what happens to B and C ?” as shown in Figures 11 and 12. Nearly half of the students (23 out of 48) answered this question incorrectly for the colored concept map, compared to only one-fourth (12 out of 48) for the uncolored one. Thus, the number of incorrect answers to these questions was twice as high for the colored concept map as for the uncolored one. This result reveals that the students had incorrectly understood the meaning of the colored links. This flaw was not exposed when the students worked on the full system as they were working on a concept map in a domain they were familiar with. Asking them questions outside this domain helped us to identify this problem. Though the changes to the user interface made it simpler and more efficient to use, it suffered from the primary drawback of being incorrectly interpreted by the students when they were involved in reasoning tasks. In the more abstract domain for the latter questions, students used the color on the arrow as an absolute. In other words, they inferred that “red”

meant “decrease” (similarly, “green” meant an “increase”) to the destination concept “B” regardless of whether “A” itself increased or decreased. Therefore, we decided not to use colored arrows in future versions of the system.

Animated Agent Evaluation

Evaluation of the animated agent was done as a separate study to the one above. This study involved 36 U.S. students aged 9-11 (fifth-grade) from the same public school as the previous study. A reasonable indicator of the effectiveness of an animated agent would be to assess task performance with and without the animation. Thus, we presented a task in which students were asked to find mistakes in a concept map and correct them. This “debugging” task involved the nitrogen cycle for plants. The concept map shown in Figure 3 had three errors: the relation between (i) “dead plants” and “plants,” (ii) “Ammonia” and “Nitrosomonas Bacteria” are incorrect, and (iii) an important relation between “Nitrobacter bacteria” and “nitrates” is missing. The control group for this study worked with the non-animated agent whereas the experimental group worked with the animated agent. Both agents used the text-to-speech synthesizer to coordinate speech and lip movements. Students were given 45 minutes, and the resulting concept maps were scored in a condition-blind manner. Our previous experiences have found students at this level find such tasks extremely difficult (Leelawong and Biswas 2008), which explains the overall low scores. However, students using the animated interface scored 1.13 out of a possible three, whereas students without the animated interface scored 0.59 out of three. These results are statistically significant ($F = 4.32$, $MS = 2.64$, $p = .045$).

Additionally, a five-point Likert scale survey and questionnaire asking students for comments on the effectiveness of the interfaces was administered. Answers were coded and evaluated using a Wilcoxon rank sum test. In response to questions about Betty’s emotions and feelings, students responded that the animated version had significantly more emotion and showed feelings ($p = .01$ in both cases). Students were marginally more motivated to teach the animated agent ($p = .07$) but were significantly more likely to want the animated agent to learn everything ($p < .05$). Students commented that they liked the agent’s facial expressions and emotions. Most of the negative comments centered around the quality of the voice of the agent that was produced by the text-to-speech synthesizer.

Discussion, Conclusions, and Future Work

This paper has presented a methodology and its implementation that has led to an improved design for the user interface as well as the animated teachable agent in our Betty’s Brain system. Two experimental studies, one that compared the new interface to the existing one, and the second that compared the animated agent with facial expressions that demonstrated some emotion with the unanimated agent have demonstrated positive results with U.S. “middle”-schools, aged 9-11. (U.S. middle schools typically encompass ages 9 through 14, but the domain of knowledge for our particular study is taught to students aged 9-11). As educational technology, our focus on design of teachable agent systems has been to create useful social interactions between virtual agents and students that promote learning in exploratory and constructivist learning environments (e.g., (Bandura 1989; Palinscar 1998)). This approach is different from some traditional tutoring systems (Wenger 1987), where the focus is on immediate correction of student errors during problem solving tasks. Though exploratory environments have been hypothesized to provide better learning opportunities for students, unless they are well-designed, intuitive, easy to use, and provide the right kind of feedback, they may often frustrate students, when they get stuck addressing difficult problems that may involve learning new knowledge as well as monitoring their learning processes (Lajoie and Derry 1993). We have been studying all of these issues in the context of our teachable agents system (Schwartz et al. 2007). While cognitive load per se was not directly measured, we believe we can reasonably infer that our redesigned user interface and the use of more natural animation for the teachable agent has helped in reducing the cognitive load that students face when teaching by creating causal concept maps, and when they monitor these maps to find and correct errors in their initial maps. This inference is reasonable because of performance and learning improvements made by the students in the absence of any other changes to the system. More specifically, our studies show that students preferred the pop-up mechanism for adding the links. This feature saves valuable screen space, which has been used in subsequent versions of the system for providing other helpful learning tools (For a newer version of the system go to <http://www.teachableagents.org/bettysbrain>). The introduction of specialized buttons for “Switch Trend” and “Switch Direction” made it easier for students to make corrections to the causal relations they were specifying in their concept maps. Of course, like many other features, this set produced a “double-edged sword.” Easier modifications helped students focus more on the monitoring task, but it also facilitated the use of a suboptimal

“guess and check” strategy. Once we discovered this, a pattern tracking agent was inserted that discouraged and sometimes prevented students from engaging in this behavior.

Another feature that we experimented with was the use of color to explicate the increase/decrease relations in the concept map. Earlier experiments conducted with college-age students (Viswanath et al. 2004) reported improved efficiency in using the system and the use of colors did not interfere with their understanding of the reasoning mechanism. In the present study, middle school students were more efficient with the colored links when they created their own maps, and in the questionnaire they indicated their preference for the colored links. However, when given debugging tasks with others’ maps, the students misinterpreted the meaning of color on the links. One interpretation of this in computer science and cognitive terminology may be that the use of color was “overloaded”, and the middle school students were not mature enough learners to handle this overloading. In subsequent implementations of Betty’s Brain, we do not associate colors with links. Instead, when Betty reasons, the borders of the concept boxes are colored green or red to indicate an increase or decrease in the particular entity. We have found that this coloring scheme helps students understand the reasoning mechanism, and it does not create the confusion associated with the colored links.

The use of the more videorealistic face with a few animated expressions has also been shown to be helpful, primarily because the students seem to be more motivated to create, monitor, and correct their concept maps. This was clear from the improved performance on the debugging tasks and the students responses to questions after they had finished their tasks. Therefore, animation is useful in the teachable agent environment, primarily because it addresses the issues of social learning and motivation that we discussed earlier. However, there is a trade-off because authoring animated agents can be expensive and time consuming. The machinery that we have developed as part of this research allows quick and reasonably believable animations for customizing different agents that we may employ in the teachable agent system. One of our future goals is to provide students with more choice, so we can easily support different learning style preferences by adjusting the personality and appearance of the agent. We can also easily change the expression and appearance of the agent to meet specifications for different domains of knowledge. These results on the utility of animation are consistent with findings for pedagogical agents (Baylor and Ryu 2003). Investigating different rendering styles for agents, such as non-photorealistic rendering (Gooch and Gooch 2001) and full body animation (Rose et al. 1998) using this machinery is a topic of future work. Allowing full body animation will allow us to incorporate gestures into the agent as well.

An important area of current research is how much scaffolding for learning the interface an animated agent can supply when coupled with enhanced content and cognitive feedback as described by Tan et al. (2006). Future experiments will evaluate how interface modifications affect learning-related outcomes. For example, many simple changes may create an interface that is sufficiently easy to use but will allow users to exploit shortcomings in the reasoning portions of the system with the result that they are able to “game” the system, i.e., have Betty achieve good results without the students themselves learning much. Also, future work in this field will explore the judicious use of colors and shapes to represent hierarchies and relationships between entities. The use of these in animations to explain the complex relations in a system will also be investigated.

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The Transformational Promise of Information and Communications Technologies (ICTs) for the Professional Education of Architects

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ABSTRACT

The ever-expanding use of new information and communication technologies (ICTs) is especially significant to professional education in relatively isolated nations such as Taiwan. Interaction with university faculties outside the country would vastly improve the Taiwanese education of architects, for example, and this is sufficient reason for the full implementation of ICTs in architectural schools in that country. This article 1) explores how ICTs hold a promise for transforming the process of professional education in architecture, 2) examines the issues and difficulties of implementing ICTs in the teaching of architecture, and 3) discusses how a greater use of ICTs in architectural education would enhance both the ability of students to work collaboratively and the opportunity for professors to enjoy much greater participation and collegiality in the world-wide academic community of architectural educators. Particular attention is given throughout the paper to the epistemological and educational paradigm of constructivism and the cultural considerations of implementing ICTs in an Asian nation such as Taiwan.

Keywords

ICTs; professional education; collegiality TPCK; academic collaboration

Introduction

This paper attempts to answer three fundamental questions about the possibility of using ICT to transform the delivery of education to professional architects. First, what are the potential benefits of ICT for teachers and students in higher education professional programs such as architecture? Secondly, what are the issues that all too often act as barriers to the full development of an ICT-rich learning environment in higher education? Finally, what are the particular issues involved in implementing ICT to transform the teaching of architecture in a rapidly developing nation such as Taiwan?

The response to these research questions requires, at the outset, a selective literature review regarding the use of ICTs in professional education, specifically in architecture. The review focuses, first, on the relationship between the rhetoric and the practice of implementing ICTs in educational systems, and, secondly, on important cultural issues involved with this kind of implementation. One recurring theme is the idea that ICTs have the potential for radically transforming educational practice; another is the idea that ICTs promote the constructivist paradigm of epistemology. The review concludes with an examination of the use of ICTs in architectural schools, concentrating on both the successes and the difficulties that have been observed so far.

The literature review will be followed by a compact case study of how ICT has been used in the educational system of Taiwan to date. This, in turn, will be followed by a theoretical grounding of the discussion in the educational paradigm of constructivism. A full discussion of the use of ICT in professional education, particularly in relation to Taiwan, will conclude the paper.

A Brief Review of the Literature

The first thing a review of the literature reveals that there has been an abundance of positive claims published in recent years about the promise that ICT holds for transforming higher education in the twenty-first century, but there has also been a disturbing lack of empirical evidence to support these claims. Stensaker *et al.* (2007) sum up the situation very well when they describe their own findings about the difficulty of putting ICT theory into practice at universities: “. . . it is not the visions, the visionaries (institutional top-management) and the economic foundations that seem to be lacking, but an effective link between, purpose, people, and pedagogy inside the institution” (p. 431). Wong and Li (2008), in one of the more substantial empirical studies of how ICT is actually used in contemporary

education, confirm the need for a multi-layered approach to instituting and assessing ICT, one that combines lofty educational goals with the day-to-day work of teachers in order to effectively manage change.

The idea that ICT is culturally embedded is taken for granted by experts in the field of education. For example, Zhang (2007) makes an important distinction between the pedagogical cultures of Western nations and Eastern nations. While the West has a long educational tradition, dating back to Socrates in ancient Greece, of individual discovery through debate between learners and teachers, the Eastern educational tradition, based on Confucius in ancient China, emphasizes what Zhang (2007) calls “a group-based, teacher-dominated, and centrally organized pedagogical culture” (p. 302). In fact, in almost all Eastern nations the implementation of ICT in educational settings is controlled by central government agencies, and usually these agencies have national plans that are geared specifically to meet the economic demands of globalization and the social demands of the information age.

One recent study is very informative about the impact of ICT on the professional education of architects. Based on research in the United States, Japan, and Europe, Andia (2002) reviews how the architectural profession has received and incorporated ICT over the past thirty years. His most significant finding is that professional architects have used ICT mainly for the purpose of enhancing existing practices that have been in place for at least one hundred and fifty years, while architectural schools have used ICT to transform both architectural imagination and architectural practical possibilities. Andia points out that ICT has dramatically affected architects at both the level of skills and the level of professional culture. From the 1970s to the mid-1990s architects developed computer-assisted design (CAD) techniques, and since the mid-1990s architects have made great use of the networking capabilities of ICT to improve the design/build process. Architectural academia, however, has challenged the traditional tributary role of the profession. As the author puts it, “Schools have become experimental laboratories for creating design machines, promoting new architectural imagination and treatment of materials, and finally extending the architectural realm to cyberspace” (p. 7). Andia identifies five distinct discourses that have evolved in architectural academia since the 1950s: design methods, CAD visualization, paperless architecture, information architecture, and virtual studios. The trend of these discourses is to move the vision of architecture from the physical world to the virtual world. The question is, Can architects learn to design for both realities? This is the most important challenge that professional architectural education faces at the present time.

The Case of Taiwan

The great economic growth enjoyed by Taiwan throughout the 1980s and the 1990s encouraged the national government to institute broad educational and social policies designed to place the country at the center of the new information age where it can take advantage of the wealth of opportunities offered by globalization (Tu & Twu, 2002). Most of the attention of implementing ICT in Taiwanese education has focused so far on the K-12 curriculum, with the principal use of ICT being computer-aided instruction (CAI). One empirical study indicates that CAI has provided a modest improvement over traditional teaching methods in Taiwanese schools (Liao, 2007). Nevertheless, it appears that, despite the Ministry of Education’s rhetoric about the benefits of ICT for education, ICT itself is seldom taught as a subject in the K-9 schools of Taiwan, thus delaying the learning of basic computer skills (ChanLin *et al.*, 2006). The implementation of ICT in the Taiwanese educational system is still in the early stages, but it certainly has not yet realized its promise.

There is, however, some evidence that ICT has been incorporated, rather tentatively, into higher education settings in Taiwan. Yang (2008) reports that one university class was taught to use Socratic dialogues, the basis of constructivist learning, through asynchronous online delivery by a creative professor and several teaching assistants. Young and Ku (2008) describe a joint online distance education project carried out collaboratively by a university in Taiwan and a university on mainland China, something that would have been unthinkable without the benefit of ICT. Chiu (2002) discusses the ways in which computer-assisted design (CAD) has been used in one Taiwanese architectural school, though this article also emphasizes that CAD is only a tool and that human management skills for dynamic organization is actually more important than ICT. Nonetheless, there is growing optimism on many campuses that ICT is destined to transform higher education in Taiwan, particularly the education of architects and engineers, mainly because of its potential for increasing collaboration and collegiality among faculty members.

ICT and Constructivism

The hands-on, exploratory, interactive nature of ICTs, particularly the Internet, causes them to gravitate toward the postmodern epistemology and educational theory of constructivism. In fact, if constructivism had not already existed, it seems likely that ICTs would have invented it to explain how they operate. According to Murphy (1997), “Technology is increasingly being touted as an optimal medium for the application of constructivist principles of learning.” When educators speak about ICTs transforming the teaching and learning process, they always mean that the new process is learner-centered, not teacher-centered or even knowledge-centered. Moreover, constructivist epistemology contends that knowledge is not based on an objective reality that is discovered; instead, knowledge is created or invented by learners actively giving meaning to their engagements with problems (Jonassen, 1991). Some argue that this meaning is based on individual experience, while others believe that it is socially situated (Ernst, 1995). Either way, as Means & Olson (1997) point out, constructivist pedagogy holds the promise of transforming the relationship between teachers and students in the direction of empowering learners to be much more active and interactive in the classroom:

Teachers will design the overall structure for project activities and provide the resources that students need to do them, but students will have much more responsibility for their own learning and for producing finished products that meet high standards. Teachers will function as roving coaches, helping individual students or groups over rough spots and capitalize on the ‘teachable moment’ within the context of the students’ engagement in their work. (p. ix)

This is what Means & Olson call “The Vision” of technology-supported constructivist classrooms.

Constructivism is not new. In fact, this epistemological and educational paradigm resides at the heart of Western civilization in the teaching method of Socrates who elicited knowledge from students by asking them carefully-chosen questions. Human reason, leading to the discovery of eternal ideas beyond individual experience, after the manner of the ancient Greek philosophers Plato and Aristotle, was glorified during the European Renaissance, culminating in the philosophical writings of Descartes and the founding of modern science by Newton. Nevertheless, beginning in the seventeenth century European philosophers started to question what humans can actually know through the senses and rationality. Locke, Hume, and later Kant all argued that objective reality, independent of the person experiencing it, is unknowable. Once this sceptical attitude became fairly well established among intellectuals, the development of constructivism as an epistemological and educational theory was inevitable (von Glasersfeld, 1989; Hawkins, 1994).

It seems fitting that the strongest progenitor of constructivism should be the early twentieth century American philosopher John Dewey (1897; 1902; 1938) whose teachings are known as pragmatism. This school of philosophy rejects the duality of ideas and objects in favor of the theory, adapted from Darwin, that human beings know the world by interacting with it. Dewey’s philosophy is called pragmatism because he believed that the purpose of intellectual inquiry is not to understand reality apart from experience, but to learn how to function in the best possible way within any given situation. Dewey called his theory of epistemology instrumentalism, a term that has virtually the same meaning as constructivism (Field, 2007).

Discussion

A. A Word about the Benefits of ICTs

The benefit of ICT for students – at least according to the enthusiasts – is that it will help transform them from being passive and uncritical receptacles of past knowledge into being active and creative learners, ready to take responsibility for the future. The benefit of ICT for teachers is that it will allow them to interact more freely and collaboratively with students to foster social change. But that is only the beginning. ICT networks offer the possibility of great professional development in the form of the immediate sharing of research and theoretical discourse anywhere in the world. Collegiality is fundamental to the profession of education, especially at the university level, and ICTs have already created vast networks of teachers and professors that span the globe.

It is impossible to overestimate the value of these networks to the education of professional architects. As Andia argues, architectural schools have already evolved into centers of experimental ICTs, particularly in the field of

design. Leading architectural schools in America, Europe, and Japan are capable of sharing the newest technologies with architects, professors, and students in more marginal areas, such as Taiwan, and it would be foolish of universities in lesser developed nations not to take advantage of ICTs to keep them current and competitive in the profession of architecture. It must be remembered that architecture is project-driven and almost totally at the mercy of economic forces.

B. Some Issues with ICT and Some Possible Solutions

A recurring theme in the discourse on the use of ICTs in education is the frustrating, but apparently inevitable, gap between theory and practice (Condie & Livingstone, 2007; Haydn & Barton, 2007). Loveless & Ellis (2001) sum up the situation perfectly:

We feel that the introduction of these technologies into classrooms and schools is having an impact on teaching and learning that does not necessarily reflect the ways in which children and young people experience and appropriate the technology in their lives outside school. Neither is the prophetic claims being made about the role of ICT in learning being realized in classroom practice as a whole. (pp. 1-2)

What then is the problem? There is a tendency among enthusiasts of ICT, who take for granted the belief that everyone should get on board and share the progressive journey to the future, to blame some teachers for being old-fashioned. Jordan & Jameson (2005) point out that radical change will not occur in the profession of teaching until it occurs among teachers as a whole, and they offer much practical advice about converting oneself and one's colleagues to the cause through such practices as holding positive discussions with fellow teachers and avoiding political in-fighting about matters of authority.

In contrast, however, to the assumption that ICT is a given for contemporary education, Dale et al. (2004) argue that "learning," "teaching," and "ICT" are not de-contextualized absolutes, but are, in fact, all spaces that are constructed in any given situation, and therefore the relationships among them are negotiable. This means that educators need to be wary about any rhetorical claims about the implementation of ICT. These authors even suggest that the implementation of ICT in education might be more supply-driven, from an educator's perspective, than it is demand-driven. In other words, policy makers, both at the institutional level and at the state level, might be more committed to implementing ICT than educators sometimes are. If this is the case, the problem might be at least as much vertical as it is horizontal.

Unwin (2007) describes this aspect of the problem precisely: "Technologies in education have often been seen and used as providing the answer to all our educational problems. ICT is no exception, often being promoted by politicians (and sold by retailers/software manufacturers) as the solution to efficient learning" (p. 300). Both states and universities need to appear technologically ascendant in order to "sell" "higher education to the public in the marketplace of the global village. Unwin's main argument, however, is that the implementation of ICT in higher education affects the professionalism of university teachers. He admits that constructivism provides a general theoretical framework for teaching with ICTs, but he also contends that even within this provisional paradigm higher education teachers often do not have the proper pedagogical training in ICT to be able to integrate these new technologies into their teaching, and even if they did have the training, they would still find it difficult to keep up with the constant and rapid changes of ICT.

Unwin believes that the best theoretical solution to date for the problem of ICT training for higher education professionals is TPCK, or Technological Pedagogical Concept Knowledge, a construct developed by Koehler et al. (2004; 2007) and Mishra & Koehler (2006). TPCK is a kind of knowledge that combines technology and content with pedagogy. Not just knowledge about the content of a course and knowledge about the technology available, TPCK is knowledge about the appropriate pedagogy for combining content and technology. In other words, TPCK integrates, in a complex fashion, what an educator should know and how he or she should use technology to teach that knowledge. The value of TPCK, according to Unwin, is that it does not treat technology as knowledge separate from content and pedagogy – the way that educators are usually taught ICT. He gives the example of learning to use PowerPoint but not learning the content and pedagogy for which it is best fitted. TPCK overcomes that failure, and Unwin believes it is a valuable pedagogical model for training future educators in ICT.

Laurillard (2002) calls into question the theoretical framework of constructivism itself as a proper pedagogical model for any but the highest form of education:

To support students properly in their own exploration of what is known in a field, where its frontiers are, and where they might be extended is extremely costly in staff time. Guidance is a labour intensive process, which means that any one academic can only service a small number of students. Assessment is also labour intensive, as each case must be judged on its own merit, not in terms of a pre-defined "model answer." And working at the frontiers of knowledge is essentially a lonely task done by individuals and very small groups, not amenable to any form of mass education or support. That is the proper model of post-graduate education, but that is where it must be confined. (p. 2)

Laurillard's practical reminders are sobering, and they tend to make the glowing prophecies of the many ICT enthusiasts sound glib indeed. It should be noted here that even at the Harvard Graduate School of Design architectural professors found the implementation of ICT as a pedagogical method extremely time-consuming and labor intensive, seriously straining the resources of the university (Wiske *et al.*, 2001).

Certain questions about implementing ICT for pedagogical purposes will not go away. Why is there such a gap between promise and practice? Who is to blame for the gap? Is ICT being forced upon the education system by enthusiasts and policy makers eager to be up to date and to compete in the global marketplace? Is constructivism, the educational paradigm that is always associated with ICT, appropriate for any level lower than postgraduate studies? Scholars need to continue examining these issues carefully. They also need to examine another issue -- the cultural context of ICT -- perhaps even more carefully.

C. Technology Is Not Neutral

Loveless (2000) argues that ICTs are not neutral tools for learning, but are instead "cultural artifacts" in the hands of both students and teachers. As such, they are affected by, and they affect, the culture in which they are found. These effects are likely to be profound in some cases. Studies on the ways that ICT affect educational systems, such as Davis *et al.* (1997) and Davidson (2003), generally agree that the new technologies hold considerable promise for enhancing the quality and availability of education in virtually all areas, but that they cannot simply be grafted onto old methods of teaching and learning. ICTs demand their own accommodations, and when these accommodations are recognized and used, the resulting enrichments can be manifold. And yet the cultural changes associated with implementing new technologies are bound to be materially transformative but ideologically disruptive.

Professional education in architecture is not immune to cultural changes, and many schools of architecture have eagerly jumped on the ICT bandwagon both in their traditional course offerings and in courses designed to meet the continuing education needs of professional architects and designers. This enthusiasm is reflected in a flurry of publications on the subject in scholarly and professional journals in the field. Whole conferences have been devoted to the uses of information and communication technologies in architectural, engineering, and design education. Indeed, a review of such conferences reveals not only a significant number of them, but several separate organizations devoted to the study of, or advancement of, the use of information and communication technologies in professional education in architecture. Cheng (1996, 1997, 1998, and 1999) has been particularly prolific in advocating a stronger role for ICTs in architectural education. Her works have both described and advocated the use of ICTs in studio-based instruction and in instruction in graphic design.

The Taiwanese educational model for architecture, following the ideas of Schön (1984), has evolved from apprenticeship systems into studio-based, tutorial environments. The design studio is currently viewed as a learning environment in which skills and values can be developed within a spirit of open inquiry. The model has served students and professionals well in many respects, but both constituencies need ways to incorporate rapidly-advancing technologies into both education and practice. These programs, like other professional education programs, are currently in upheaval, at least in part because of the perception that new technologies will inevitably transform them. Eagerness to adopt new methods, as well as fear of the outcomes in adopting them is characteristic of the professional architecture education in Taiwan today. We have already noted how disruptive the epistemology of constructivism, the ideological framework of ICT, can be to Asian educators. Taiwanese universities and professional programs often lack modern perspectives and remain mired in traditional methods, so much so that both teaching and professional practice fail to meet the nation's needs, despite the government's claim that the nation is

committed to modernization and global economic competitiveness through the general adoption of ICT (e-Taiwan Project, 2005).

In Taiwan pedagogical changes are taking place in a setting of rapid social and political change. Not only is there a long-standing conflict between mainland Chinese communists and Taipei democrats (Gu, 1996), mirrored by the local conflict between the Kuomintang and the Democratic Progressive Party (Hsiao, 2008), but recently a neo-Nazi party, the National Socialist Association, has been formed by university graduates and students (Turton, 2007). It is significant to note that at the heart of this radical new party's doctrine is a commitment to return to the traditional ideals of Confucius. Such young intellectuals are not likely to be sympathetic to the Western ideology of constructivism underpinning the educational use of ICT. It seems reasonable to assume that these encompassing political and cultural changes will also affect how educational changes occur.

Will professional educators in Taiwan, specifically professional educators in architecture, embrace the changes and challenges attendant with the new ICTs, even while they are managing the political, professional, and institutional changes occurring around them? Wang's impassioned (2008) plea for a total transformation of architectural education through the implementation of ICTs is certainly understandable in the context of Taiwanese society as a whole. Future research needs to focus on the acceptance and use of ICTs in architectural education in Taiwan in order to shed some light on how effective such technologies can be as they are adopted amidst a turbulent world of social change.

Conclusions

This paper has attempted to explain how the expanded use of ICT is currently changing pedagogical practice, particularly in the professional education of architects in developing Asian nations. ICT was demonstrated to have great pedagogical promise, but there is still a large gap between its transformative potential for education and its actual performance to date. ICTs encourage students to become interactive learners, and they offer teachers, particularly those in higher education, a means for conducting and sharing research beyond all previous limitations of time and geography and culture. Moreover, through the effective use of ICT educators can assist society as a whole to grow toward greater inclusiveness and progressive social change. The principal problems associated with using ICT for educational purposes appear to be a persistent failure to find a link between theory and practice and the difficulty of training teachers to use ICT creatively, although the recent introduction of Mishra & Koehler's (2006) concept of TPCK may soon change that.

The general pedagogical difficulties associated with implementing ICT in higher education are seen to be complicated in Taiwan by cultural considerations, particularly the Asian reluctance to accept a new technology so strongly associated with the Western epistemology of constructivism. Nevertheless, there is optimism that the professional education of architects in Taiwan will continue to grow and become more competitive through an expanded use of ICTs.

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Learning with Technology: Using Discussion Forums to Augment a Traditional-Style Class

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ABSTRACT

There is considerable evidence that using technology as an instructional tool improves student learning and educational outcomes (Hanna & de Nooy, 2003). In developing countries, pre-university education focuses on memorization, although meeting the mission of AUST requires students to manage technology and to think more independently. This study examines the impact of incorporating a discussion forum on the achievement of university students enrolled in a Distance Education course, Educational Technology Department at Ajman University of Science and Technology (AUST), United Arab Emirates. The study was conducted with 34 students divided into two sections, one a treatment group and one a control group. Both sections were exposed to the same teaching techniques covering the same course material on Distance Education. Four weeks after the course had commenced they were given the same teacher constructed test. However, after the first test, the treated group was exposed to the use of a World Wide Web (WWW) interactive discussion forum. At the end of the semester-long treatment period, a final test was given to both groups, and student scores were analyzed for any statistically significant difference. Questionnaires and interviews were also conducted to see if students had enjoyed the experience. The results of the study indicated that students in both groups showed learning improvement over the course of one semester, but discussion forums had an obvious impact on student achievement and attitude in distance learning/ educational technology course.

Keywords

Computer mediated-communications, Blended learning, Student performance, Technology integration, Collaborative learning

Introduction

In view of the fact that “internet connections are only as useful as the people teaching with them” (Rivero, 2006), today, many educational institutions use web-based learning environments to deliver materials to, and communicate with, their students. These web-based learning environments could be ready-made products such as Blackboard or WebCT or internally developed personalized systems. In AUST’s case (Ajman University of Science and Technology), United Arab Emirates, an electronic, ready-made Learning management system was still in a trial period and thus it was on the university's Local Area Network (intranet) rather than the internet. Thus, students could not access it from their dormitories or homes. Consequently, we created a substitute or at least some form of support to the existing Learning Management Systems, which resulted in our internally developed and personalized Web-based discussion forum (figure 1).



Figure 1. Main page of the AUST Web-based forum

Rationale

The use of this technology is not new in highly developed and technically sophisticated countries; however, the use of *E*-technologies as a means of instruction in education in many developing countries is "still *in its infancy*". Emphasis in *pre-university* education was heavily based on rote learning, Memorization based-assessment method resulting in less creativity and individuality among students in a teacher-centred, traditional behaviourist stimulus-response learning model.

The problem with *traditional models* is that they can help students achieve only a fraction of the quality education they need in an informational age. On the other hand, the main mission of higher educational institutions in general and AUST in particular, is to educate students for the telecommunications/information technology revolution age. Today, students have to develop the competencies they need to live, learn and work successfully in a rapidly changing society. Therefore, this requires a shift to the *constructivist information processing model* as a replacement of, or at least as a support to the traditional learning / teaching model. Martin (2003) guaranteed that "as theories of learning have developed, so has the model of the learner, from a model of an empty pot to be filled with knowledge...through a behaviourist one of the learner as enthusiastic rat to be rewarded for displaying remembered behaviour or knowledge, to a constructivist model of an individual creating and re-creating his/her map of existence and planning/re-planning the way through it". (p. 5)

Research findings revealed that for the constructivist learning "...the teacher, as facilitator, is responsible for process design, creating the climate for learning and making resources available" (Dewald, 2003: 48). Alternatively, in the *traditional* approach, the roles of authoritarian teacher and passive learners still exist. The stress is on the teacher's role; the teacher must do all the work of analyzing and explaining the tasks through a structured sequence as the leading vehicle for learning (Tam, 2000).

It is believed that technologies that facilitate resources can be used effectively to promote lifelong learning, and support learner-centred approaches by being vastly available. However, in spite of its remarkable contribution to humanities as a whole, specifically to developing countries, technology is also "...creating new gaps within societies as well as between developed and developing countries, particularly through the so-called "digital divide". Now more than ever before, we need to achieve a more equitable sharing of knowledge and a smoother transfer of technology. Universities have a considerable role to play in bridging these gaps but they must do so within a context that is shifting as we speak" (UNESCO, 2001).

So, the institutions have to be committed to ensure that technology is used effectively to enhance learning/ teaching processes. Eventually, good online teaching according to Chickering and Ehrmann (1996) "...needs to eschew materials that are simply didactic, and search instead for those that are interactive, problem-orientated, relevant to real world issues and that evoke student motivation" (p.7).

Therefore, this study is a part of AUST's efforts in employing a variety of web communication technologies to aid passive traditional "*hush and listen*" learners, to be an active part of the knowledge acquisition and knowledge construction processes, and to detect their perceptions of using supplemental web- based instruction. It also examines ways in which teachers continue re-examining their traditional teaching strategies in light of new possibilities offered by web-based instruction.

Goals and Research Questions

The main goal of this study was to determine whether students who were enrolled in the class using online discussion forums significantly increased their distance learning knowledge and skills and contributes to positive student attitudes.

For this reason, statistical analysis of data collected in this study was performed to seek answers for the following research questions:

1. Do the pre-test scores for the treatment group and the control group show significant differences at the starting point of the study?

2. Do overall distance learning knowledge and skills increase, from the pre-test to the post-test, among the treatment group and the control group?
3. Does the integration of the discussion forum as an interactive instructional tool have a positive effect on students' attitudes?

Literature Review

E-learning and Learner/ Instructor

In his article "The Emerging Online Life of the Digital Native," Prensky (2004) compared the internet generation to the generation that grew up in the age before the internet. He concluded that today's digital information-communication-technology is an important part of a student's life; therefore "our students have changed radically. Today's students are no longer the people our educational system was designed to teach." The following chart (1) summarizes his article to illustrate the unique characteristics of digital natives.

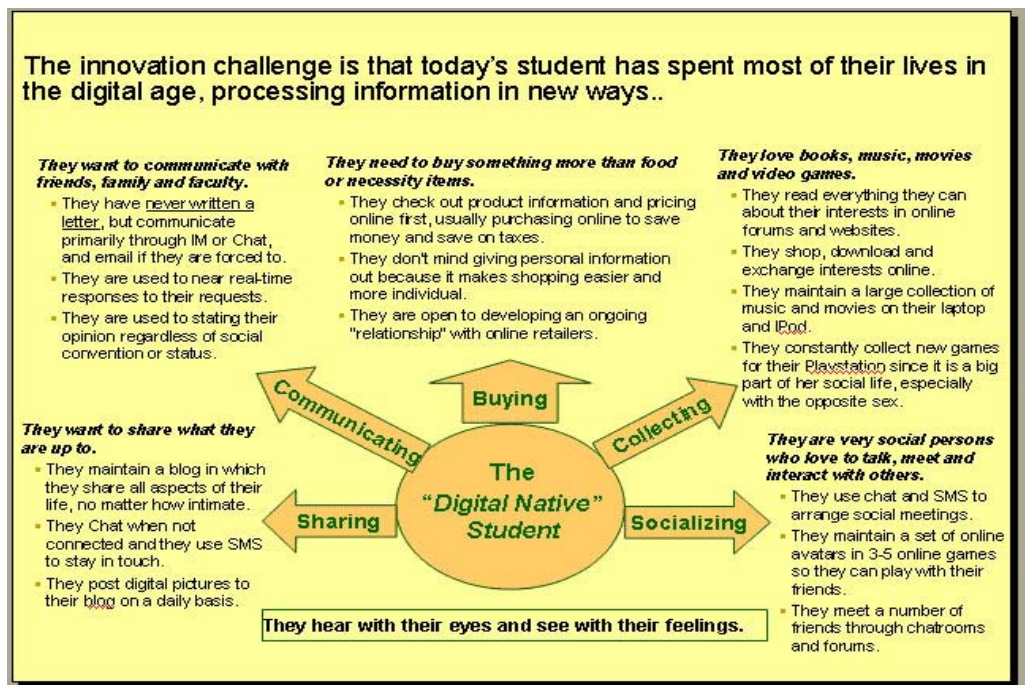


Chart 1. Adopted from Prensky as cited by International Turnkey Systems

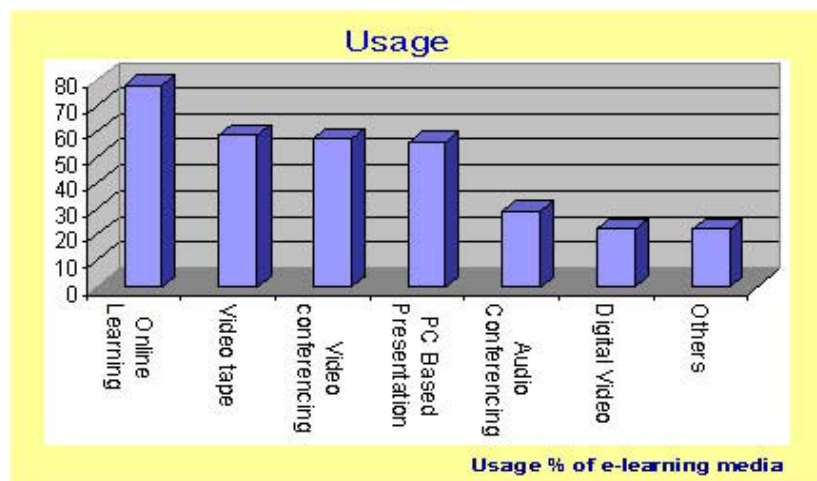


Chart 2. Adopted from International Data Corporation (2003) as cited by International Turnkey Systems

A review of related literature revealed substantial research indicating that online technology is the most used by today's students as illustrated in chart 2:

The key lessons learned from previous studies have led us to believe that online teaching and learning are not perfect "yet" (Alvarez, 2005). Alvarez stated that, "the online environment is not the ideal setting for all types of learning. Classrooms are not perfect either..." E-learning is not a 'one size fits all' magical solution that can resolve any educational problem and there are definitely some disadvantages to this type of learning. Consequently, there is no way to guarantee that 100% of the e-learning content will reach 100% of the intended audience. According to Shepherd (2003), "e-learning can be used on a just-in-case basis, but it can also be deployed just-in-time". Therefore, there is an urgent need to clearly understand what the right circumstances are and how e-learning can help to produce the best results.

Discussion Forums

According to Kearsley (2000), the most significant applications of computer-mediated communication in E-learning environments are discussion forums. Web discussion forums provide a way for students to extend the classroom discussions. It provides better cognitive and exploratory learning (Haggerty et al., 2001), increased student-to-student discussion and cooperation (Kassop, 2003; Stodel et al. 2006), superior learner empowerment (Kassop, 2003), and upgraded critical thinking skills (Shapley, 2000; Collison et al., 2000).

The literature reviewed provided valuable knowledge regarding the effect of discussion forums and "e-technology" on learning outcomes. However, judging the efficacy of student learning based on learner feedback in online learning is particularly difficult because of the following:

- The literature is limited and the overwhelming majority of it focuses on American students (Eom & Wen (2006), Wheeler (2006), and Young (2006). However, the difference between reported computer usages between different racial/ethnic groups continues to intensify as reported by Sax, et al. (2004). Accordingly, "there is a strong possibility that e-learners in Taiwan or Hong Kong have a different idea about learner needs, success, and satisfaction than e-learners in the American Southwest who attend a local community college." (Tomasson 2007)
- In view of the fact that the emergence of online learning in the late 1990s created many unique challenges for the teaching/learning process, much of the online learning research had been done in the late 1990s and early 2000s. Undoubtedly, due to the enormous expansion of online learning, this research is considered to be somewhat outdated.

According to Parson (1998), discussion forums can be ineffective for the teaching/learning process and thus can end up as an open-ended, non-productive learning activity. Researchers emphasized the need of knowing how the new technology can affect learning outcomes when it is used by different types of learners under different circumstances. It is obvious that just making discussion forums available does not result in effective use. In several cases, forums were created with eagerness but ended up in a digital disappointment. Oblinger (2003) gave the following elaboration on this problem:

- Making use of Web-based communication technologies in the teaching/learning process does not guarantee critical thinking and effective learning and teaching.
- The accessibility of music/video, freeware, and the ability of file sharing, does not mean that "digital work is everybody's property".

Accordingly, further inquiry is required to establish the extent to which research conducted on other continents of the world is applicable to the non-traditional American student. Ajman University of Science and Technology (AUST) believe that its goal as an educational institute is to stay as "an organization that is constantly making its future rather than defending its past." (Hamel & Valikangas, 2003, p. 54). Therefore, AUST is taking into consideration the need for continuous enhancement of its educational practice in order to prepare students for the intuitive changes that such technology produces.

The Study

Research Design

The purpose of this study was to determine the effects of using discussion forum on the achievement of the educational technology freshman students. The study was based on a quasi-experimental design; the non-equivalent-groups design (Campbell & Stanley, 1996). The independent variable was the incorporation of discussion forum into the instruction, while the level of student achievement on the post-test was the dependent variable of the experiment.

Methodology

The research study was implanted in a first year level educational technology course (580122, Introduction to distance education). Having an actual course for the Web-based discussion forum research provided a normal environment for the study as shown in figure 2.

| Courses | | | |
|---|--|-------------------------|---|
|  | Distance Learning with Dr.Zuhriah | 37 Posts in 3 Topics | Last post on April 16, 2006, 11:17:21 PM in Re: A Stantard Proje... by sharifah |
| خدمات / services | | | |
|  | Chating with learners تحدث مع باقي المتعلمين chat with each other and discuss what you want!! | 12 Posts in 2 Topics | Last post on December 14, 2005, 11:04:51 PM in Formula For Success by fatimaalmahdi |
|  | Translations ترجمة المقالات المنشورة | 15 Posts in 2 Topics | Last post on March 20, 2006, 10:32:05 PM in Re: First translatio... by iman_abdullah |
|  | Downloads تنزيل المقالات المنشورة للقررات | 15 Posts in 2 Topics | Last post on March 15, 2006, 12:15:41 AM in Re: Distance Educat... by fatimaalmahdi |
|  | Tests أختبارات سابقة | 14 Posts in 3 Topics | Last post on March 13, 2006, 10:18:56 PM in Re: @#1610;@#1575;@#... by fatimaalmahdi |

Figure 2. Distance learning course on a Web-based forum

The study was conducted with 34 students from the Department of Educational Technology, AUST. The study was designed so that there was a treatment group to whom the discussion forum was administered and a control group to whom the discussion forum was not administered. The control group used the textbook and other course materials that had been previously adopted for use in this course, while the treatment group used the discussion forum. The design of web-based discussion forum was based on the John Keller's ARCS Model (1987). According to this model there are four steps for endorsing and supporting motivation in the learning process: Attention, Relevance, Confidence, and Satisfaction. Based on this, and in order to motivate students to participate, students were asked to respond to a weekly topic in order to gain 5% for participation. Both groups were tested their first test on the 4th week of the 2nd semester of 2005, prior to the discussion forum's introduction, and a final at the end of semester on the 16th week. Therefore, the first test for both the treatment group and the control group was considered as pre-test and the final exam considered as a post-test.

Analysis was conducted only for students who remained in the study from pre- through post-testing and took their test on the assigned date. A total of 4 students were excluded (that is, about 2 students per section), primarily because they were absent on the days of the tests.

Instrumentation

Two instruments were used in this study:

- Multiple Choice Tests
- Student Questionnaire and Interview

Multiple Choice Tests:

In order to rule out any effects caused by a teacher on a course taught by two different teachers, the same teacher taught both treatment and control classes. The tests were instructor-made, paper and pencil, objective, multiple-choice tests. The instructor is experienced and has been teaching this course for the last four years. Therefore, through an item analysis at the end of the term, and after the deletion of the questions that are missed by top-level students, a pool of reliable questions was available.

Since the testing purpose was to evaluate the students' understanding of the main concepts and ability to understand or perform specific competencies, the pre-test and a post-test were constructed. Each of the two tests contained a set of 50 multiple choice questions. The questions had five choice answers rather than four with only one correct answer in order to reduce the likelihood of guessing the correct answer. In addition to answer choices such as "all of above" or "none of the above" or "both a & b" were eliminated for being confusing and misleading. The purpose of this procedure of setting up the questions is to make the correct answers hard to recognize unless the student truly understands the material. The test was also validated using experts' judgment from the Faculty of Education and Basic Sciences, AUST. Their comments, advice and recommendations were taken into consideration.

Student Questionnaire and Interview:

The questionnaire included five questions around the attitudinal aspect of the students' experience in using the web discussion learning method to support face-to-face accomplishments. The questions and the percentages of responses yes or no to each are shown in table 1. Results were analyzed to see if students enjoyed using the discussion forum, and whether they think that the web interaction with peers and instructors enhanced their learning. The open-ended questions were mainly for getting more elaboration on the students' answers for the questionnaire.

Table 1. Learning experience questions and responses

| Question posed | Yes | No | Elaborate(optional) |
|---|------|-----|---------------------|
| Is combining face-to-face classes with discussion forums potentially useful? | 93% | 7% | |
| Does 24/7 instead of 3 hrs/ week class interactivity support learning? | 86% | 14% | |
| Is there anything that you currently do in face-to-face classes that might be better done online? | 86% | 14% | |
| Can discussion forums be an alternative to face-to-face classes? | 33% | 67% | |
| Would you like to participate in a similar exercise in the future? | 100% | 0% | |

Although it was not compulsory to explain or elaborate on student's own answers, students were encouraged to do so. They were assured that giving reasons for answering "Yes" or "No" will give greater weight to their answers. Accordingly, 86% of the students chose to explain their answer.

Students answering "yes" to this to questions 1, 2, 3 and 5 gave the following reasons for supporting the web discussion forum:

- Reading different replies can promote new ways of thinking and help generate new ideas.
- Assist students in developing language skills.
- Offers wide range of views and ideas, generate course-related questions and feedback.
- Prepared students to work together in class, to discuss and evaluate each other's work.
- More intellectual interactions and connections, lead to more possibilities of shared knowledge, understanding, thinking and reflection.
- Acquiring help quickly and easily makes learning accessible
- Reinforce the skills taught/learned in a face-to-face setting.
- Can encourage shy students to feel more confident

- Gives a chance for all students to participate, while class discussion is short and limited to few students

The following are a summary of reasons for answering “No” to questions 1, 2, 3 and 5:

- Students found themselves struggling against time consuming, endless, addictive, distracting discussions and debates.

In response to question 4, a great bulk of respondents (67%) prefer to use the discussion forum as a support to the traditional face- to- face education. According to them, an online instruction is not out to replace face-to-face instruction but to enhance it; hence, they answered “no”. Moreover, respondents specifically mentioned the positive features found in the traditional classroom environment that virtual learning environments may *lack*. These features include:

- The visual & social communication cues
- The richness of face-to-face personal interaction
- Face to face cues may result in lack of trust

To build on the previous students' responses, the researcher developed an interview composed of two open-ended questions:

1. What do you think has worked well in the discussion forum experience? Specify the best activity in this experience.
2. What do you think should be done differently in the online discussion process?

Selected students were interviewed during the development of questions in order to confirm that the questions and responses were interpreted as intended. Students had different interpretations that led to their various answers. Consequently, this led to major modifications made to improve reliability and reduce the risk of misinterpreting questions.

Subsequently, all students were interviewed for an average duration of approximately 15 to 30 minutes per student. The two questions were in English but to exclude the language "barrier," questions were translated to Arabic.

Constructive data for this study was collected through the open-ended interview questions. Here is a summation of students' comments and conclusions drawn by them:

1. What do you think has worked well in the discussion forum experience? Specify your favourite & satisfying activity in this online experience.
 - Flexibility of learning: accessing the course resources anywhere/anytime.
 - Cost savings: no travelling or spending extra time away from work.
 - Self-paced: revisiting the material many times.
 - Track learners: provide proof of their work and skill development.
 - Accessibility: on-demand access.
 - Faster learning: skipping familiar material.
 - Consistent message: avoiding the problems associated with different instructors.
 - Immediate feedback: inspiring, reinforcing and motivating.
 - Satisfying experience: participating actively.
 - Updated and revised content: updating by uploading the revised version.
 - Vivid and ‘lifelike’ experience: using rich media when appropriate.
 - Recalling & retention: presenting information in more than one medium.
 - Risk-free environment: eliminates the embarrassment of failure in front of a class.

More than 80% of students who used the discussion forum acknowledged that the most favourable and satisfying online activities are:

- Interacting and *sharing* ideas and materials with other students and with the instructor
 - Taking exams online, turning-in and getting back assignments with prompt feedback and grades.
2. What do you think should be done differently in the online discussion process?

- Wider range of Information and Computer/Technology Skills necessary to successfully accomplish the assignments.
- Handy documentation on help and tips for getting the maximum value from the resources.
- More explicit connections between the discussions in class and the online discussions to help see the online discussion as an integral to the class and not as an add-on or luxury activity.

The Participants

Participants in this study were 34, first-year, female students enrolled in Educational Technology course during the second semester of 2005 at AUST, Fujairah Campus, United Arab Emirates. They were mainly from the UAE and Sultanate of Oman and their ages ranged between 18 and 24. Twenty percent of them were married and a 10% are working part-time. About 50% lived in the dormitories. In addition, all of the participants had completed studying two major courses in the first semester, 580111 Instructional Print and Audio Media 3(1- 4) and 580112 Modern Educational Technology (3 credit hrs). They had also been oriented to electronic learning system at the beginning of the 2nd semester. They are familiar with IT and have access to the Internet. English is the medium-of-instruction of educational technology AUST. Therefore, their English language is proficient and Arabic is their mother-tongue. Therefore, to get the maximum experience, they were allowed to use both languages with a recommendation not to use Arabic unless it is very necessary, translation services were offered to help them deeply understand the course materials as shown below.

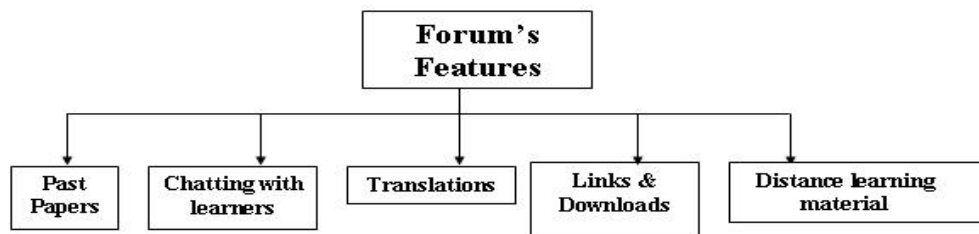


Figure 3. Features of the forum

The Treatments and Interventions

Web-based discussion forums are much like face-to-face discussions: they require preparation and active management in order to facilitate student learning. However, online environment needs special care for producing a comfortable conferencing system that helps students communicate clearly without the aid of the body language. As a result, the intervention did not start at the beginning of the course; it started after the first test. This helps student get acquainted with their class environment and classmates, and feel more protected and confident. The objectives, units, project tests and other components of the course syllabus were discussed with both groups and then the treatment group got introduced to the discussion forum and its features.

Since students know that others will read their posts, they often take their time, and put significant thought and effort into them before posting. The web based exchange of ideas results in higher quality work than if students were left on their own. For this reason, roles and responsibilities for discussion forum participants were analyzed (figure 4).

To help students become comfortable with the discussion board, the intervention starts with the instructor posting a welcoming introduction; followed by asking students to privately reply to their instructor expressing their first impressions of online communication. Subsequently, students participate in a group discussion about previous knowledge of the course topic, and their objective for taking the course. Students were encouraged to share links to websites pertinent to the course. These non-graded tasks are designed to ensure that all students can get connected to the conference and know how to send messages.

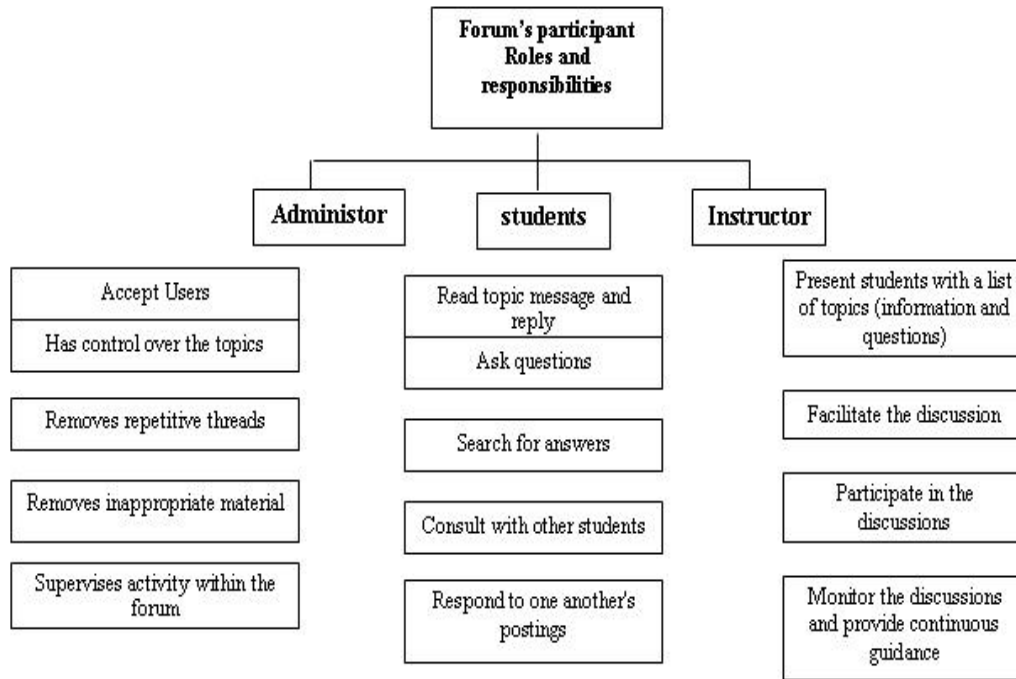


Figure 4. Roles and responsibilities for discussion forum participants

To enhance integration of the discussions, and help participants show their insights, students are asked to use their discussions as data for an assignment; the assignment is to evaluate a distance learning course/program. Since an evaluation rubric has to be designed, each week students have to discuss one topic related to criteria for effective distance learning according to their course units which are listed below:

- Foundations of Distance Education
- Definitions, History & Theory
- Distance Education Technologies
- Instructional Design & Distance Education
- Learning Strategies at Distance Education
- Teaching at Distance Education
- Assessment and Evaluation For Distance Education
- Copyright and Distance Education
- Distance Education Research

Students initiate, discuss and reorganize the comments made; analyzing the main contributions, and incorporating their peers' comments as illustrations or examples in the assignment.

Since the point of web discussions is to have students talking to each other the first two weeks of the intervention, the instructor's presence was intensive at first, gradually reducing with time. Instead, senior students were encouraged to participate in the discussion and take the role of the instructor. This strategy worked well and proved to be beneficial to all students.

Data Analysis and Findings

Multiple Choice Tests

The program used in the computational steps of this study was SPSS version 11. The hypothesis is that the means are equal; the alternative hypothesis is that they are unequal.

The first step was to determine the distance education knowledge and skills level before starting our interventions. So, it was very important to determine whether there was a statistically significant difference between the *control group (C1)* and the *treatment group (T1)* in the in 1 pre-test score. For finding out the difference between the treatment and control mean pre-test scores, a *t-test* was used. The measure used in this analysis was the raw score of the distance education exam (pre-test). Analysis of the mean scores shows that results were statistically equivalent. Therefore, *there were no significant differences* at the starting point of the study as shown in the table 2.

Table 2. The mean of pre-test scores for both treatment and control groups

| | Paired Differences | | | | | t | df | Sig. (2-tailed) |
|----------------|--------------------|----------------|------------|---|---------|------|----|-----------------|
| | Mean | Std. Deviation | Std. Error | 95% Confidence Interval of the Difference | | | | |
| | | | | Lower | Upper | | | |
| Pair 1 C1 - T1 | .36667 | 4.03762 | 1.04251 | -1.86929 | 2.60263 | .352 | 14 | .730 |

The next step was to decide whether there is an improvement in students' achievements during the semester. This can be done by determining whether there was a statistically significant difference between the *pre-test and post-test scores for students in the treatment group (T1 &T2)* and the *in the control group (C1&C2)* For this, a *t-test* on the difference between the mean pre-test and post-test scores for both groups was used. Analysis of the mean raw scores shows that *students, in the treatment group, using the web based discussion forum program showed significant improvement in overall test scores* from the pre-test to the post-test. While, *students in the control group, using their current textbook programs showed moderate improvement in overall test scores* from the pre-test to the post-test. These differences are statistically significant at the 95% level of confidence as shown in the Tables 3 and 4 below.

Table 3. The pre-test and post-test scores for students in the treatment group (T1 &T2)

| | Paired Differences | | | | | t | df | Sig. (2-tailed) |
|----------------|--------------------|----------------|--------------------|---|----------|--------|----|-----------------|
| | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval of the Difference | | | | |
| | | | | Lower | Upper | | | |
| Pair 1 T1 - T2 | -7.83333 | 4.56566 | 1.17885 | -10.36171 | -5.30496 | -6.645 | 14 | .000 |

Table 4. The pre-test and post-test scores for students in the control group (C1&C2)

| | Paired Differences | | | | | t | df | Sig. (2-tailed) |
|----------------|--------------------|----------------|--------------------|---|--------|--------|----|-----------------|
| | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval of the Difference | | | | |
| | | | | Lower | Upper | | | |
| Pair 1 C1 - C2 | 2.40000 | 4.33919 | 1.12037 | -4.80296 | .00296 | -2.142 | 14 | .050 |

In addition, it was crucial to compare the achievements' improvements in both groups to validate the efficacy of the intervention/treatment by verifying if there is a *significant difference between the control (C2) and treatment group (T2) on the post-test*. For this, a *t-test* on the difference between the mean post-test scores for both groups was used. This analysis shows that *the overall mean post-test scores for the treatment and control group are significantly different as shown in the table 5 below*.

Table 5. Scores of the control group (C2) and treatment group (T2) on the post-test

| | Paired Differences | | | | | t | df | Sig. (2-tailed) |
|----------------|--------------------|----------------|--------------------|---|----------|---------|----|-----------------|
| | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval of the Difference | | | | |
| | | | | Lower | Upper | | | |
| Pair 1 C2 - T2 | -5.06667 | 1.22280 | .31573 | -5.74383 | -4.38950 | -16.048 | 14 | .000 |

Student Questionnaire

When questioned about the experience of using web-based discussion forums as a way of discussing topics related to the course instruction, the majority of students (93%) stated that it was beneficial and 86% of the participants considered interactivity as an essential factor for effective learning. The participants felt that traditional class discussions are short and limited to few students, while the discussion forum is more comprehensive, lively, gives a chance for all students to participate, and better prepared students to work together in class. The web forum can also deeply benefit shy students who may have problems contributing in face-to-face discussions. This set the foundation for intellectual interaction and collaborative learning.

Even though most students found web discussions to generate critical thinking and meaningful learning, there has been some concern regarding the idea of using discussion forums as an alternative to face-to-face traditional learning; indicating that the most noteworthy difference between face-to-face and discussion forum conversations is the absence of body language clues which help with interpreting the learner's reaction to remarks and ideas of classmates. In addition, they indicated that the process was relatively time-consuming, addictive, sometimes distracting and thus inappropriate to completely replace the traditional face-to-face setting.

Therefore, 93% of the participants favoured combining face-to-face classes with discussion forums, and confirmed that often forum discussions built basis of in-class comments and discussion. With respect to the third question, participants agreed that reading others' replies is a fruitful experience that would not normally be obtained in a traditional face-to-face setting. They also added that it was rewarding to see shared views with others; it provided support to what they had been studying and boosted their self-esteem. All treatment group students suggested that they increased their knowledge as a result of this experience, and would be happy to participate in a similar one in the future. Comparisons between the students' responses are illustrated in the chart 3 below.

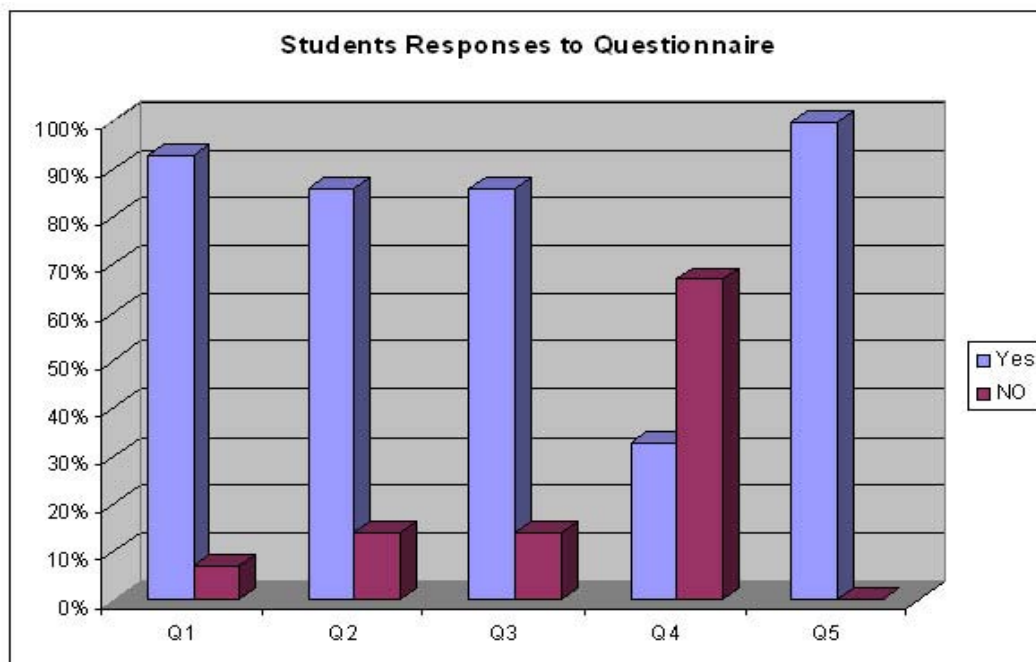


Chart 3. Comparison between the students' responses

Student Interview

The data obtained from the interview conveyed the students' positive comments that in turn indicate students' positive perception of the discussion forum as teaching/ learning tool as shown in the chart 4.

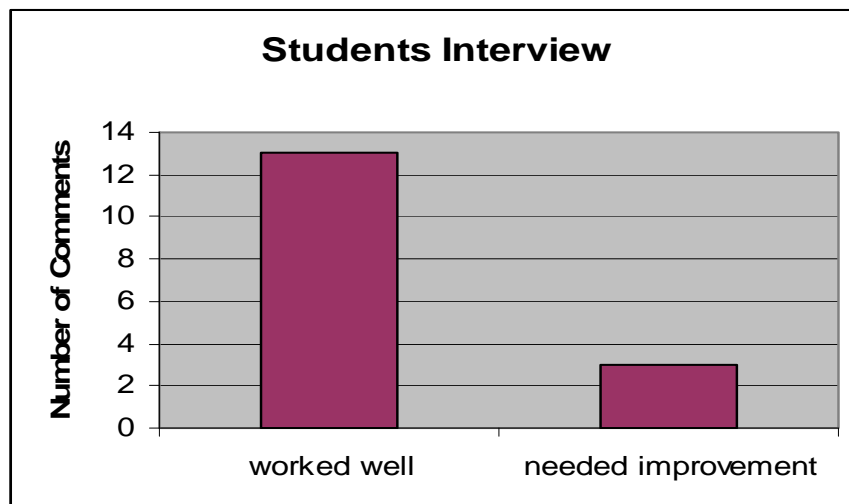


Chart 4. Students' perceptions of the discussion forum

Generally, the results of the above questions suggest that students found online discussions beneficial and useful to them. Many students felt improvement in their learning skills and quality. Their positive feedback describe it as flexible, convenient, attractive, motivating, satisfying, safe, rewarding and “learner-friendly”.

Students' negative responses to the quality of online discussions are also essential for improving the current teaching quality, and help identify some of the weaknesses. Weaknesses included: not enough training for some students needed in Information and computer/technology skills, more guidance on how to implement the acquired skills, and more handy documentation on help and tips for getting the maximum value from the resources. They also suggested a stronger connection between in-class material and online discussions, stressing possible links between online and face-to-face discussion, so that the interaction can be unbiased to bring participants the best of both modes. This in turn helps reinforce using discussion forums as a teaching/learning tool to support in-class activities, and helps students develop mastery of concepts and emphasize the students' understanding of their course skills.

The interview data also reveals that our targeted students share similar perceptions of the most beneficial activities in their discussion forum environment to be interaction, sharing ideas and materials with other students and the instructor, in addition to turning-in and getting back assignments with prompt feedback and grades. While weaknesses seemed to be associated significantly with: the necessity for more tips, help and training in information and technology skills, in addition to developing a stronger link between discussions in class and online.

These comments will be considered when creating the evaluation criteria framework to design online courses and a basis for future online discussion forums research and design.

Lessons Learned

Some of the lessons learned from implementation of discussion forums for students unaccustomed to constructivist and e- learning:

- Knowledge cannot simply be generated by instructors and linearly transmitted to students to use; it is built up through the synthesis of social experiences that occur in the learning environment. Therefore, discussion forum learning environment requires *careful and complete preparation* for the effective experience where students become the focus and thus plays an active role in the teaching and learning process. This learning environment should help create opportunities to generate and construct new knowledge through interactions between instructors and learners, learners and learners, and learners and learning materials.
- The discussion forum has to be learner centred, task oriented, non-threatening and a safe space where the student could ask and express their feelings and convey their ideas and point of view freely and openly. Students will not engage as fully as they desire if they do not feel safe and comfortable.
- As with the introduction of any new technology into the classroom, we must be able to:

- Demonstrate the new technology's value,
- Point out both its contributions and its deficiencies,
- Justify its positive contribution because students must be able to trust that the actions taken by authorities are correct.

Perhaps the most important lesson learned was regarding how to evaluate the success of present experience. Since different sample size, year group, technological skills and different teaching/learning styles present different needs and demands, contributing to the outcomes of the experience; there was consensus that it has to be an ongoing evaluation process. Consequently, there is a definite need for AUST to engage in practical and ongoing monitoring, reporting, evaluating activities, it is necessary to make the appropriate adjustments to meet its goals.

Implications for the Future

The Goal:

To develop new student-centred modes of learning, and improve learning environments to better fulfil the needs of the community, workplace, and the AUST learner.

Actions Recommended for Achieving Goals:

Throughout the student's learning experience at AUST, students are encouraged to take an average of three courses (12 credit hours) through out-of-classroom experience along with other non-traditional activities such as: E-learning, internships, learners' instruction etc. So there is a true value in web-based teaching/ learning. Online learning can be attained almost entirely at the student's convenience, and it can be tailored and customized to their needs; enhancing all students' higher education experience including on-campus resident students (Lorenzetti, 2005).

Furthermore, based on the author's personal experience, the author believes that the logistical flexibility offered by online learning can provide new educational opportunities for Arab women. Especially for women wanting to get married while studying, or pursue graduate studies while building their career or raising their kids. Online learning can enhance and increase their access to education to achieve their desired goals.

Moving learning beyond the recall of facts needs greater flexibility in the provision of learning. This is perceived as a chief motivation for developing online classes to support the convenience and flexibility of college study. Implementing an e-learning program requires careful consideration such as:

Furthermore, to become successful E-learners and prepare them to be active participants in an online environment; it's compulsory to carry out appropriate preparatory training for faculty, staff and students. To avoid any confusion or frustration students may face, instructors are encouraged to gradually increase student online involvement over time as follows:

- To help integrate the online and face-to-face mediums, instructors should acquaint themselves with the available resources, and then analyze what works well in asynchronous and synchronous environments. Consequently, instructors could develop tasks where some aspects are to be completed online and others through face-to-face setting. When doing so, the instructions and directions are supposed to be explicit without being complicated
- In view of that, students are encouraged to use the web as Course Electronic Recourse Centre, a media-rich interactive site that provides faculty and students with comprehensive resources in this manner:
 - *For students:* It will include all materials required for the course such as syllabus, course calendar, PowerPoint presentations, handouts, exercises, recommended references and links to related sites etc.
 - *For Instructors:* Course instructor's support in the forms of implementation manual, technological support, assessment and evaluation tools and professional development to foster sound decision making on how to best manage students learning activities in a an online environment
- Accordingly, start shifting other course activities to online mode. For example, each instructional unit began with a lesson plan that can be linked to online learning activities, video, exercises, and lab activities. Then, introduce a digital "drop in box" to hand in assignments, followed by online testing, posting of the graded online test results in the students and instructors grade books, tracking student performance ...etc until students and instructors are ready to meet the challenges a whole online course.

Study Limitations

This study has several limitations which may have affected the results. These limitations include the small size of the samples (total number of the class); the gender of the participants being limited to females; varied students' experience with the internet; the instructor's teaching style and his familiarity with the web based learning environment and the nature of the course itself, results might be quite different with other courses.

Discussion and Conclusion

Both the treatment group using the web-based discussion forum and the control group using their current adopted textbook and other assigned materials, showed significant learning improvement over the course of a full semester. Both groups accomplished gains in all distance education skill areas and in their overall raw scores. Yet, when comparing the level of improvement for both groups, the treatment group showed more significant improvement. The data presented in this study also indicates that, in addition to these earlier findings, the researcher's assumption proved to be correct, in that students do better because they participate more and are more actively involved in the web discussion forum. It also affirmed students' satisfaction with on-line discussion and instruction especially when e-learning is used as a supplement to face-to-face instruction.

The findings of the study affirm that educational systems in the Arab world need to further progress and advance. As more countries participate in the global economy, Arab countries have recognized that technology is not a luxury, but is a must for competing in a global economy and workplace and that "the best way for Arab youth to assimilate globalization, is to continue to harness the vehicles of information and communication technology" (UNDP, n.d.).

On the other hand "it cannot be assumed that simply providing teachers/learners with appropriate tools and task materials will result in their spontaneous engagement with contextual thinking.....the potential of computer mediation to foster knowledge depends less on what learners use, than on how they use it".(Thompson, 1999) The results of this study have thus demonstrated the integration of e-technology to traditional learning situations in which students are passive recipients of information and facts. It illustrated the conversion of the one way flow of instructions to threaded discussion to encourage active engagement with course material which in turn leads to a better and more meaningful learning experience.

Thus, this study is considered as a preliminary analysis that needs further investigation on best practice in the electronic and blended learning environment, which best matched the vision and needs of AUST and similar institutions in the region and worldwide.

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A Study of Multi-Representation of Geometry Problem Solving with Virtual Manipulatives and Whiteboard System

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ABSTRACT

In this paper, the development of an innovative Virtual Manipulatives and Whiteboard (VMW) system is described. The VMW system allowed users to manipulate virtual objects in 3D space and find clues to solve geometry problems. To assist with multi-representation transformation, translucent multimedia whiteboards were used to provide a virtual 3D space in which users could express their mathematic solutions and reasoning with a three dimensional model which can be viewed from any perspective. The purpose the VMW is to promote a multi-representative construction model with which users can easily organize their thinking manually and symbolically to solve geometry problems, based on the pedagogical theory which states: “*Children would construct their geometry concepts from multiple representations like mapping the concrete items to abstract ideas through physical or mental manipulation*”. The proposed system was evaluated with one pilot study to investigate its perceived ease of use and usefulness. Furthermore, students’ solving strategies were analyzed using their manipulations in the 3D space and solutions recorded in the whiteboards. The results showed that the proposed system was perceived as useful, and helped students to understand the processes of geometry problem solving, such as using various solving strategies, as well as exposing geometrical misconceptions. In the future, researchers also aim to apply the multi-representative construction model to knowledge construction in other domains.

Keywords

Constructivism, Geometry problem solving, Multi-representative construction model, Virtual Manipulatives, Web3D

Introduction

Geometry is one of fundamental methods which people use to understand and to explain the physical environment by measuring length, surface area and volume. For this reason, enhancing geometric thinking is very important for high-level mathematical thinking, and it should be developed with spatial interaction and manipulation in daily life (Clements & Battista, 1992; Tan, 1994). However, in traditional classrooms, geometry learning is usually conducted only through the description of text, 2D graphs and mathematical formulas on whiteboards or paper. In some important topics, such as measuring the area and volume of 2D or 3D objects, traditional teaching methods often focus too heavily on the application of mathematical formulas, and lack opportunities for students to manipulate the objects under study. Consequently, many students can memorize the formulas and even appear to succeed in their course work without fully understanding the physical meaning of the math formulas or geometry concepts (Tan, 1994).

Tan (1994) suggested that the development of understanding of concepts such as the measurement of area and volume should come from the experience of covering and stacking manipulations, so that when formal mathematical concepts and formulas are introduced or applied, children would actually understand the formulas and their meanings. This implies that the construction of the geometry knowledge should be acquired via manipulating spatial objects (concrete experience), brainstorming (imagery concept) and writing symbolic solutions (abstract representation) (Battista & Clements, 1991, 1996).

Therefore, to provide an environment to facilitate such deep, rich learning, researchers employed both computer 3D graphics and simulations to create a multi representative construction model, offering learners more flexible ways to organize their thinking with manipulation (like coordinating, restructuring and comparing operations) and symbolic

terms, such as text, graphics and speech. Researchers incorporated translucent multimedia whiteboards into a 3D virtual space, combining Virtual Manipulatives and a Multimedia Whiteboard to facilitate geometry problem solving (Figure 1), to create a new tool called the Virtual Manipulatives and Whiteboard, or VMW. In the VMW system, learners can solve geometry problems by manipulating virtual objects or exploring the problems from various viewpoints in 3D space. Then, learners can choose appropriate viewpoints in the 3D space and generate their own translucent whiteboards atop their images, to write down math equations or textual explanations. By providing students with an easy way to move back and forth from the concrete to the symbolic, the tool facilitates children's thinking in geometry problem solving as per the pedagogical theory which states: *Children should construct their geometry concept from multiple representations like mapping the concrete items to abstract ideas through physical or mental manipulation.*

VMW system also recorded user's manipulation into a database. Analysis of physical manipulation in a 3D scene and symbol expressions of the same on whiteboard provides insight into the thinking of each learner, such as strategies used, and misconceptions held. Thus the VMW system also provides teachers with valuable information, which can be used to guide the development of subsequent lessons.

Perceived acceptance of the VMW system was investigated using the Technology Acceptance Model-based questionnaire. The obtained results show that VMW students found the tool to be useful and easy to use.. The combination of learners' manipulations and their solving content on the whiteboard was also analyzed. Varieties of solving strategies were found and some important insights into effective teaching practice were also acquired. In the future, researchers aim to extend multi representative construction model to various domain knowledge in addition to the learning of Mathematics.



Figure 1. Concrete, imagery and abstract transformation was facilitated in geometry problem solving

Literature Review

Mathematical Geometry Learning

Enhancing geometrical thinking is important, and this occurs naturally through by spatial interaction with real objects and problems in everyday life. However, in traditional education environments, geometry is most commonly taught using text, 2D images and mathematical formulas. For some important topics, such as measuring distance, area and volume, some studies have shown that such teaching method are not highly effective. Consequently, many children do not understand the physical meaning of the formulas found in their textbooks (Tan, 1994). Schoenfeld (1992) stated that "mathematics relies on logic rather than observation as its standard of truth, yet employs observation, simulation, measurement and even experimentation as a means of discovering truth". The statement reflects a growing understanding of mathematics as an empirical discipline, one in which mathematical practitioners gather "data" in the same ways that scientists do. Moreover, the tools of mathematics can support abstraction, symbolic representation, and symbolic manipulation.

As for learning the concepts of volume and surface area by children, Tan (1994) found that most children used visual perception to intuitively compare the size of objects. They usually considered one dimension for comparison even though the geometry problems concerned multi-dimensions. For example, in comparing the area of one triangle and one square; it is not easy to distinguish which one is bigger using intuition or by comparing only one dimension. Therefore, some manipulations are first needed to restructure the two shapes into one similar shape whereupon accurate comparisons can be easily made. If only mathematical formulas are used to make comparison of the areas of these two shapes, students have no experiential basis by which to understand the physical meaning of math concepts and formulas. Therefore, students develop their understanding of geometry through first decomposing, structuring, comparing and coordinating, and formalize that understanding by learning and applying mathematical formulas that are both meaningful and useful.

Virtual Reality and Manipulatives

Some studies have concentrated on conceptual learning and virtual reality (Roussos et al., 1999; Kirner et al., 2001; Moustakas, Nikolakis, Tzovaras, & Strintzis, 2005). Most of these studies are based on the constructivism approach. For example, the NICE project (Roussos et al., 1999) was one of the immersive, multi-user environments designed specifically for collaborative learning. The main activity in NICE requires students to collaboratively construct and to tend a healthy virtual garden. The NICE project employed the social constructivism approach and helped children to build virtual gardens collaboratively by learning and discussing the relationships between plant growth, sunlight, and water.

Kirner et al. (2001) developed the CVE-VM (Collaborative Virtual Environment), which provided tools to help children to build their own virtual world. It also supported collaborative learning according to the constructivism approach. Moustakas et al. (2005) also designed collaborative augmented reality as a medium for teaching by using 3D dynamic geometry to facilitate mathematics and geometry education.

Many studies used Virtual Reality and Constructivism to enhance collaborative learning, but the major difference between the VMW system and past studies is that VMW system combined Virtual Manipulatives and multimedia whiteboard to propose a multi representative construction model. In this model, knowledge is constructed through transformation of concrete imagery and abstracted representations through physical or mental manipulation. In VMW, the manipulation was defined as Virtual Manipulatives which was first proposed by Moyer, Bolyard and Spikell (2002). Virtual Manipulatives is *an interactive, Web-based visual representation of a dynamic object that presents opportunities for constructing mathematical knowledge*. Virtual Manipulatives promised to have great assets for learning because computer materials have portability, safety, cost-efficiency, minimization of error, amplification or reduction of temporal and spatial dimensions, and flexible, rapid, and dynamic data displays features. Regarding learning performance, Triona and Klahr (2003) also showed that the performance in concept learning was almost the same when taught with either virtual or physical materials.

Multimedia Whiteboard

Another feature of the proposed system is to incorporate translucent multimedia whiteboard into virtual 3D environments. We know the whiteboard or chalkboard plays an important role in knowledge construction process. For thousands of years, people have communicated about objects in the physical world using 3D models or two-dimensional drawings (Bimber & Stork, 2000). For convenience and ease of use, most people usually use 2D symbols to represent 3D physical objects in everyday life, requiring access to a 2D-sketch tool like a paper, chalkboard or whiteboard to show their ideas. In schools, teachers and students need these tools to show their ideas by writing texts and drawing graphs. Teachers generally still used traditional chalkboard or white boards to teach mathematical reasoning and calculating skills. However, use of the physical boards is constrained by the limited physical space available so that frequent erasing is required. Hwang et al. (2007) proposed using a multimedia whiteboard system without physical space limitations to improve mathematical problem solving with multiple representations. The proposed multimedia whiteboard allows students to express their thoughts with text, images or the spoken word. While using multimedia whiteboards to support multiple representations, students start with multi-model solving processes in mind and then translate their thoughts into multiple representations. The results showed most students were satisfied with the usefulness and ease of use of the multimedia whiteboard system.

The use of language to explain mathematical thinking is significantly related to learning performance and Weitz, Wachsmuth and Mirliss (2006) employed tablet PC as an electronic whiteboard and studied its usefulness to support learning activities. They evaluated faculty applications of tablet PCs apropos their contribution to teaching and learning. The result showed approximately two-thirds of the responding faculty used their tablets as a whiteboard, and approximately 90% felt that their use of a tablet for writing mathematics and drawing diagrams, charts and/or graphs had a positive impact on learning. In this study, the multimedia whiteboard allowed for abstract representations of real objects, facilitation expression of ideas, as well as annotation, mathematical reasoning, and peer communication. With help of Java Web Start technology, the client user interface of VMW system was integrated with asynchronous discussion threads (reference Figure 4). Teachers can use the whiteboard to start a new

discussion thread with an initial question and then students use the whiteboard to respond or reply to messages already posted, engaging in a potentially rich opportunity to share and discuss ideas on the internet.

Technology Acceptance Model

To evaluate functionality of VMW system, the valid measurement scales were needed to predict user acceptance of the system. Therefore, the Technology Acceptance Model (TAM) was used in this study. The TAM was developed by Davis (1989) and is based on the Theory of Reasoned Action (TRA) (Ajzen & Fishbein, 1975). In TAM, there are two beliefs focused on information system acceptance, which is *perceived usefulness* and *perceived ease of use*. Perceived usefulness was defined as the *degree to which a person believes that using a particular system would enhance his or her job performance*. The point of perceived usefulness is that if the users think a system might help some way, the attitudes they express will be positive. Perceived ease of use was defined as *the degree to which a person believes that using a particular system would be free of effort*, the point being that if users think the system is easy to use, then their attitude towards it will be positive, and increase the likelihood of continued use. For high reliable and valid measures, Davis used the step-by-step process to refine and streamline it, resulting in two six-item scales. In the context of education, TAM has been applied to educational technologies such as e-learning systems used with children (Liu, W., Cheok, A. D., Mei-Ling, C. L., & Theng, Y. L, 2000) (Shayo, C., Olfman, L., & Guthrie, R, 2000)(Hwang, W. Y., Chen, N. S., & Hsu, R. L, 2006). In this study, the proposed system was designed for upper intermediate elementary school students and their teachers.

Supporting Theories for Design

According to the literature review in the previous section, two pedagogical concepts, constructivism and multiple representation transformation, were employed to support the VMW design. For mathematics problems, especially for geometry, these two theories were considered together and employed to support our design for help students to build their geometric knowledge. Constructivism provides the pedagogical support to design VMW for students to construct their own knowledge, while multiple representation transformation gives the support of cognitive symbol translations to facilitate students' learning by transforming various forms of construction.

Constructivism

From the previous literature review, we know the emerging media holds promise to improve classroom learning activities, and the geometry concepts can result from experience in covering and stacking manipulations. The use of computer-based simulations has been recognized as a powerful tool to stimulate students to engage in the learning activities and to construct meaningful knowledge. As Whiteside (1986) stated *Computer simulation-based instruction is useful to reach the analysis, synthesis, and evaluation--hierarchical levels in Bloom's taxonomy*. Now from the constructivist viewpoint, using computer 3D virtual reality and its manipulation to support mathematical geometry learning activity is beneficial. Constructivists claim that *individuals learn through a direct experience of the world, through a process of knowledge construction that takes place when learners are intellectually engaged in personally meaningful tasks* (Conceicao-Runlee & Daley, 1998). Chittaro and Serra (2004) claimed that Constructivism is the fundamental theory that motivates educational uses of Virtual environments as follows:

"Our type of experience is a firstperson one, that is a direct, non-reflective and, possibly, even unconscious type of experience. On the contrary, third-person experiences, that result from the interaction through an intermediate interface. In many cases, interaction in VEs (Virtual Environments) can be a valuable substitute for a real experience, providing a first-person experience and allowing for a spontaneous knowledge acquisition that requires less cognitive effort than traditional educational practices."

Winn (1993) also claimed virtual environments can provide three kinds of knowledge-building experience that are not available in the real world; *they are concepts of size, transduction and reification, which have invaluable potential for education*. In this study, 3D computer simulation was employed to model real-world geometry problems, and learners can be deeply engaged in task-related manipulation to solve them.

Multi-Representation Transformation

In cognitive psychology, representations refer to hypothetical internal cognitive symbols that represent external reality. Lesh, Post & Behr (1987) pointed out five outer representations used in mathematics education including real world object representation, concrete representation, arithmetic symbol representation, spoken-language representation, and picture or graphic representation. Among them, the last three are more abstract and higher level of representations for mathematical problem solving (Johanna, n.d.; Kaput, 1987; Lesh et al., 1987; Milrad, 2002; Zhang, 1997).

Some learners favor visual or concrete representations, while others favor symbolic or abstract representations. Normally, students with high problem solving abilities are those who can skillfully manipulate the translation of language representation (verb or vocal), picture representation (picture, graphic) and formal representation (sentence, phrase, rule and formula). On the other hand, students with low problem solving abilities generally have difficulty in the translation of different representations in problem solving. Furthermore, since students have different learning styles, it is useful to provide various learning strategies and media to allow students to explore multiple representations in class, thereby enhancing their learning performance (Hwang et al., 2007).

To understand how the VMW system supports multi-representation transformation, we can imagine a fictitious instructional space in the classroom. The teacher and all students take their transparent whiteboards and stand around a table, where several kinds of geometric objects are placed to allow the students to study geometrical problems and concepts. Students can manipulate geometric objects or observe others manipulating geometric objects, so some ideas for problem solving or concepts underlying the questions may appear in their mind (imagery). This kind of representation transformation is from concrete manipulation or observation to imagery concept in the mind (as shown in the upper part of Figure 2). Afterward, the students choose appropriate viewpoints behind the whiteboard to view the 3D theme and write down their solutions on the whiteboard with symbol or texts, moving from imagery concepts in the mind to abstract symbols on the whiteboard.

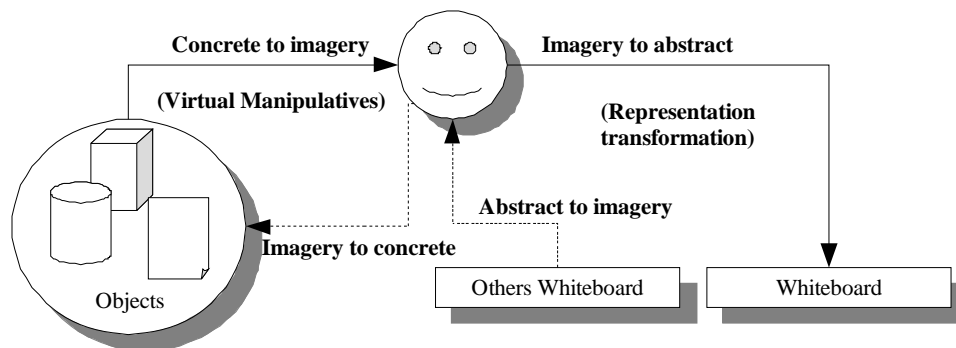


Figure 2. The process of multi-representation transformation and its inverse were shown

Students can also share their ideas via the virtual whiteboard. When students study others' solutions in the whiteboard, they may try to understand the equation and symbolic explanation (abstract to imagery) of others. Furthermore, students can validate or refute others' thinking by manipulating geometric objects (imagery to concrete). This reversed transformation was shown in the lower part of Figure 2. (abstraction \rightarrow imagery \rightarrow concrete)

Research Design

Measurement

An 18 item questionnaire with five-point Likert-type scale was used to investigate perceived acceptance of the VMW system. The perceived satisfaction and perceived improvement in geometry problem solving with the VMW system were also surveyed. The questionnaire's design was based on the Technology Acceptance Model, and involved some

aspects of multi-representation usage (multimedia whiteboard and Virtual Manipulatives). Previous study of multimedia whiteboard questionnaire (Hwang et al., 2006) was referenced to develop the new questionnaire. This study follows TAM's definition, with perceived usefulness being defined as *the degree to which a user believes that using a VMW system would enhance his or her task performance for solving geometry problem*. In contrast, perceived ease of use refers to *the degree to which a person believes that using a VMW system would be free of effort*. The scale items are worded in reference to *Virtual Manipulatives, whiteboard usage and geometry problem solving issues*.

The factors of questionnaire items are summarized in Table 4. Notice the table implies each item is corresponding to distinct factor. For perceived usefulness, corresponding factors include task performance, useful, effectively, make task easier and enjoyment. They all come from the TAM, with the exception of enjoyment. The major difference between the current study and the original TAM questionnaire design is that in the original TAM questionnaire, questions covered the entire system without looking at functional details. In order to help young students understand the meaning and intent of the questions, each item was described with a detailed description of the function of the VMW system. The factor of enjoyment was added based upon the belief that will enjoy working with a well designed system (Norman, 2004). With regards to perceived ease of use, the corresponding factors were made explicit and included controllability, ease of learning, ease of skill development and ease of use, all of which come from TAM.

The questionnaire was originally in Chinese, and was reviewed by an elementary Math teacher to make sure that students could understand the meaning of each item. All the items in questionnaire were framed in positive ways, based on the authors' review of related journal studies (Selim, 2003) (Hwang et al., 2006). In addition, the contents of students' solutions were analyzed, and their solving strategies classified and quantified into different classes.

Subjects

Twenty three 6th grade elementary students participated in this research. The evaluated period was one and half months. The students followed their Math teacher's instruction to solve eight geometry problems. The perceived acceptance of the proposed VMW system and its influences on geometry concept learning were investigated. Interviews the subjects and their content analysis were carried out to further investigate the causes underlying some interesting phenomena.

Activity Design

Since the proposed VMW system can be accessed from a website, teachers and students can easily engage themselves in problem solving anywhere and anytime if Internet access is available. In the beginning, teachers organized and stacked geometric objects to build geometry problems in the 3D space and gave problem descriptions on a virtual whiteboard. Students then started to solve problem and to express their solutions on their own virtual whiteboards. When students completed their answers, a peer review session was started. In this session, students were asked to review the answers of others and to critique their work using the virtual whiteboard. Students could therefore continually revise their answers, affirm or refute the work of others and engage in discussions of the work until the next problem was posed.

Research Tool: VMW and its Implementation

The VMW system is a collaborative tool for geometry problem posing and solving. We designed this system based on work in the literature review above. The geometry knowledge construction should be based upon covering and stacking activities. The VMW system provided virtual 3D geometric solids as a form of concrete representation and users could pose and solve geometry problems by manipulating them. These geometric solids included cube, pyramid and sphere and so on. Users could select the solids and place them into the virtual space. The operations of stacking, partition, comparison and measuring operations are explained as following:

1. **Stacking:** the stacking operation involved movement of one block at a time into configurations with other blocks. Figure 3 shows the user how to use the stacking operation to move one cube on the top of a stair. Stacking blocks was one of the most useful activities in lesson. For example, teacher could stack many different kinds of blocks into a larger one, and ask students to determine the surface area or volume. Students could use stacking operation to rearrange the blocks to help them to find solutions to the questions asked.
2. **Partition:** Sometimes it was necessary to move a group of blocks or to partition one large block into many small pieces. In Figure 3, we can see the partition operation pushed all the blue blocks forward and the original blocks were divided into two groups. The partition mechanism was made it possible to break large blocks into different layers, turning a large problem into smaller and simpler components which the students could solve in stages.
3. **Measurement:** Measurement was employed to figure out the distance between two points. It is useful to find the width and height of multiple blocks to help in calculating their surface area or volume. For example, the width of stair blocks was measured as 5 units in Figure 3.
4. **Comparison:** Comparing was employed to find the difference between two distinct stacks of blocks. The VMW system can generate shadow blocks from the existing blocks. The shadow blocks are just one pseudo-figure of the original blocks, and it cannot be stacked and partitioned. Afterwards it was possible to change the transparency of shadow blocks so that students could explore the structure of stacked blocks and make some comparisons. The shadow blocks are useful to teachers, as they can use this feature to pose stacked blocks as shadow blocks. Then students used the above operations to manipulate their own blocks to compare their constructions with posed shadow blocks.

To model the 3D geometric solids in the VMW system, the open XML-enabled 3D standard—X3D was employed, which was proposed by the Web3D consortium. To help and to realize the X3D application development, the Web3D Consortium also promoted the open Java source project Xj3D. The open source project Xj3D provides Java API and toolkit for X3D application development and SAI (Scene Access Interface) could be used to access X3D objects with Java programming languages. In this study, we used X3D to describe the virtual 3D models in the VMW system and employed Xj3D API to implement and to access X3D objects.

For the VMW system delivery and maintenance mechanism, the Java Network Launching Protocol (JNLP) was employed to maintain the consistency of the Java module or library between the clients and the server. When users login and launch the VWM system using JNLP on the web page, the newest Java module, of the VWM system (if available), was automatically downloaded, installed and executed. After launch, the client program communicated with the server by Simple Object Access Protocol (SOAP).

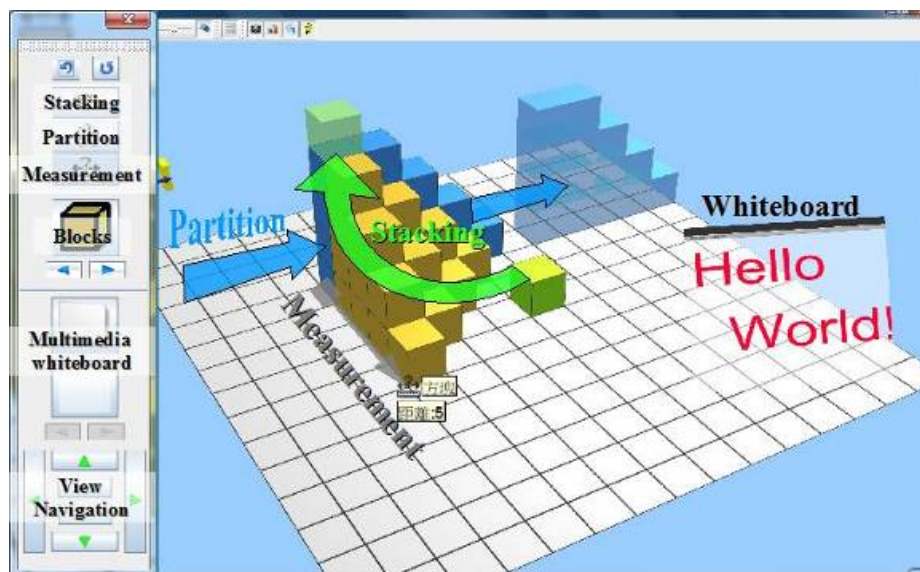


Figure 3. The manipulation tools in VMW system was shown in this figure

To support collaborative work for geometry problem solving among students and teachers, a discussion forum was employed, shown in the upper part of Figure 4. In the beginning, teachers first posed a new geometry problem with

the VWM system, in which a 3D theme was built, with a problem description given in the whiteboard. All students studied the new geometry problem given by teachers and gave their answers by clicking a circular icon in the upper part of Figure 4 to launch the VWM client program. Students could also revise their solutions many times by replying their previous answers or by giving comments to others solution via others' discussion thread. The VMW system, combined with discussion thread, provides an asynchronous collaboration model. Its implementation is easier than a synchronous model. From the viewpoint of learning, Won et al. (2003) and Hwang et al. (2006) indicated that the asynchronous collaboration offers flexibility to the students. With the assistance of a semi-automatic administration system, students can study the materials of the course, take exams, as well as being assessed. Following the social constructivism and the scaffolding theory, this type of system gives students the support needed to acquire and consolidate new learning.

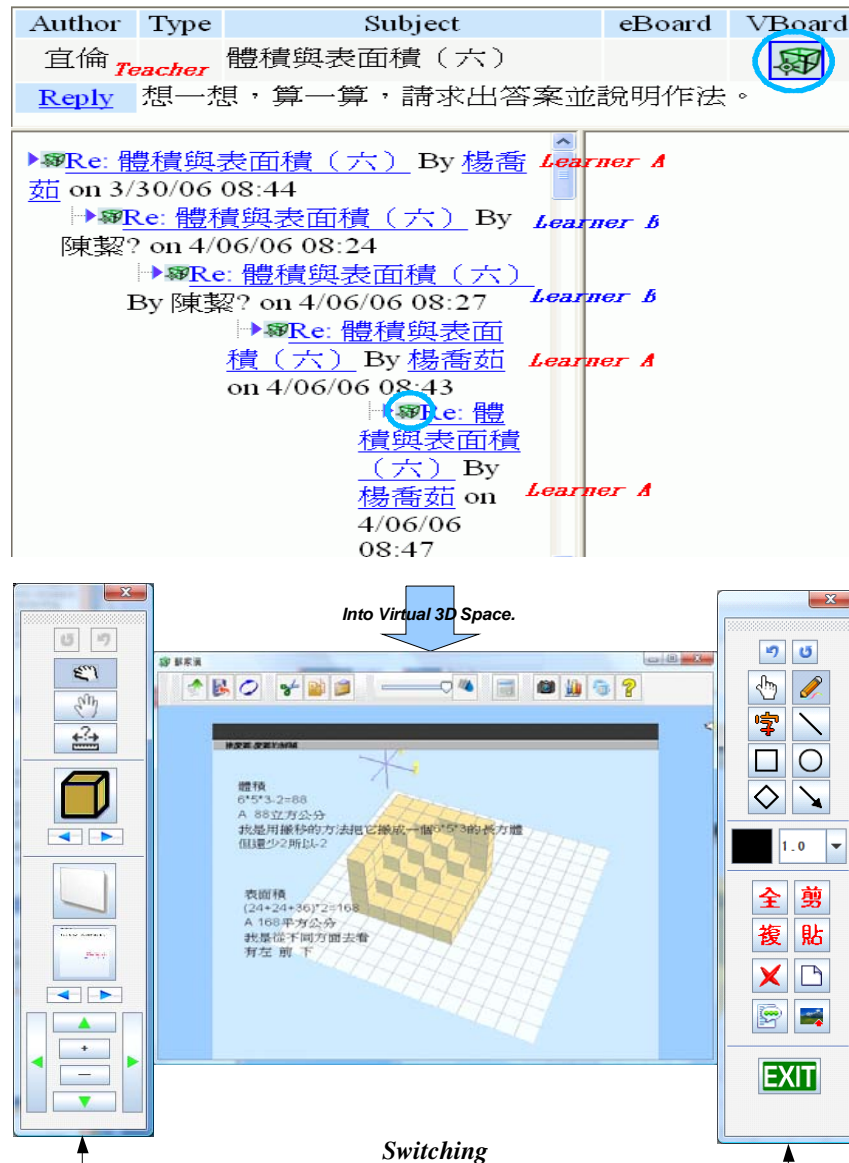


Figure 4. VMW system and discussion threads were integrated for asynchronous collaboration

Students can study the problem by manipulating 3D objects, and then choose appropriate viewpoints to create their own translucent whiteboards. The whiteboards can help them to find out the solutions via observation of the manipulated 3D theme behind of the whiteboards (the lower part of Figure 4). Moreover, after the teacher initiates a

new question, students can collaboratively discuss the question by generating their own translucent whiteboards combined with 3D scene behind. In Figure 5, there were three whiteboards that were created asynchronously. One was created by the teacher and two were created by students. Teacher used one whiteboard to describe geometry problems, while on the students' whiteboards they discussed how to solve the problem together.

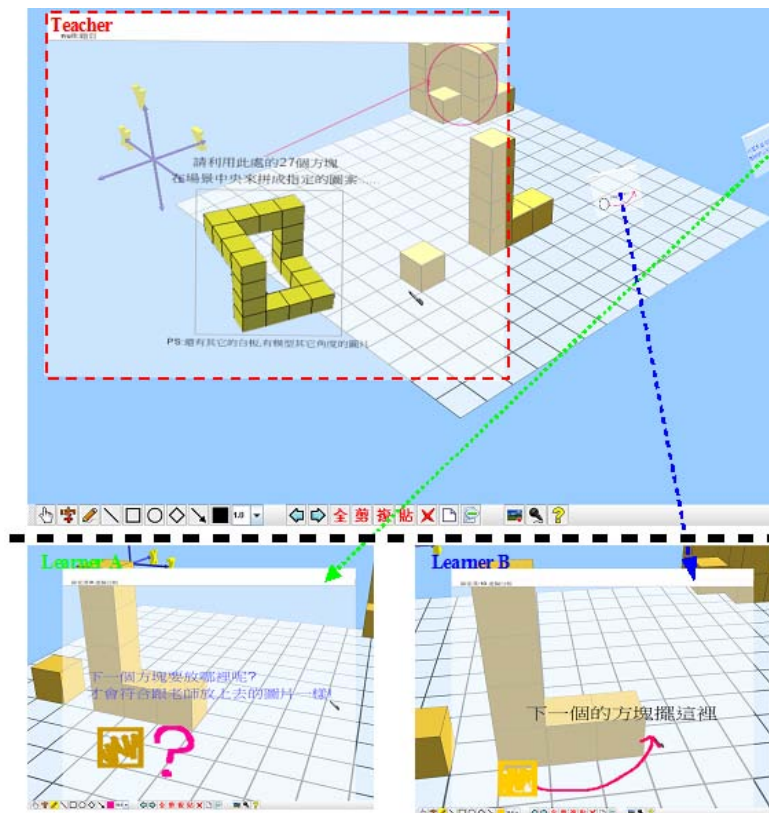


Figure 5. Teacher and students were asynchronous communication with whiteboard

Results and Discussion

Questionnaires

The questionnaires were sent to the 23 subjects and the exclusion of responses from incomplete questionnaires resulted in a total of 20 valid questionnaires. Table 1 shows the reliability of the questionnaires. It was found that the value of Cronbach alpha in the two dimensions, namely perceived ease of use and perceived usefulness, were both higher than 0.8 which is deemed acceptable. Table 2 and 3 show the results of perceived usefulness and perceived ease of use in the questionnaires, respectively. The subjects agreed the VMW system was very useful and the values were higher than 4.0 out of 5.0 on average. Furthermore, it was found that most subjects agreed that the VMW can help them to use different representations for solving geometry problems as well as facilitating and broadening their thinking from different viewpoints in the 3D theme. Meanwhile, they think the VMW can help them to show their solutions more completely.

Significantly, the high scores on the perceived usefulness questionnaire showed the proposed system and the multi-representation transformation mechanism were considered to provide some help in geometry problem solving by students. Most questions for assessing usefulness of the system were related to multi-representation, such as using 3D block as the concrete representation and using the multimedia whiteboard for expressing ideas with abstract symbols.

As for ease of use, most subjects had a positive attitude toward the VMW system. However, some perceived ease of use items revealed that the children had some trouble using the VMW system. Teachers found that although the whiteboard was integrated in a virtual 3D space, some students preferred using pen and paper for reasoning when they were exploring the 3D scene. The whiteboards were therefore only used for writing down their final solutions. Based on evidence gleaned from interviews, we know this was because that some students felt more comfortable when they used pen and paper for Math reasoning work. To promote students' use of the whiteboard tool in addition to pen and paper, researchers have decided to implement some calculating widgets to help with Math reasoning in a future release of the VMW system.

Importantly, according to the observations, the students were highly motivated by the interesting, fresh, new 3D manipulative software. Such an effect may have caused students to put more effort than usual into using the tools to explore geometry problems. Therefore a longer study is needed to determine if student enthusiasm and interest stemming from the novelty of the new tool was more responsible for improved performance than the tool itself.

Table 1. Reliability analysis for perceived acceptance questionnaires

| Part | Questionnaire | Cronbach alpha |
|------|-----------------------|----------------|
| 1. | Perceived usefulness | 0.90 |
| 2. | Perceived ease of use | 0.82 |

Table 2. Perceived usefulness

| NO | Perceived usefulness | SD | D | U | A | SA | Ave. |
|----|--|----|---|---|----|----|------|
| | | 1 | 2 | 3 | 4 | 5 | |
| 1. | Teacher uses voice recording and 3D blocks to organize and pose geometry question is clearer than using text description only. | 0 | 1 | 4 | 8 | 7 | 4.05 |
| 2. | I find it useful to have free viewpoints to solve geometry problem. | 0 | 0 | 3 | 6 | 11 | 4.04 |
| 3. | Using text writing, free-sketching and voice recording which provided by multimedia whiteboard meets my requirement to solve geometry problem. | 0 | 4 | 8 | 8 | 4 | 3.80 |
| 4. | Using 3D blocks to design geometry problem promotes me to think from wide angle. | 0 | 0 | 3 | 10 | 7 | 4.20 |
| 5. | I find it useful to use VMW system to show my solution completely. | 0 | 0 | 5 | 9 | 6 | 4.05 |
| 6. | Using VMW system gives enjoyment to me for solving geometry problem. | 0 | 1 | 6 | 5 | 8 | 4.00 |
| 7. | I find it useful to place multimedia whiteboard in different viewpoints for solving geometry problem. | 0 | 0 | 1 | 12 | 7 | 4.30 |
| 8. | Using VMW system helps me to learn geometry problem solving. | 0 | 0 | 5 | 7 | 8 | 4.15 |
| 9. | Using VMW system gives clues to me for discovering solving strategy | 0 | 1 | 7 | 8 | 4 | 3.75 |

SD: Strongly disagree, D: Disagree, U: Unsure, A: Agree, SA: Strongly agree, Ave: Average

Table 3. Perceived ease of use

| NO. | Perceived ease of use | SD | D | U | A | SA | Ave |
|-----|--|----|---|---|---|----|------|
| | | 1 | 2 | 3 | 4 | 5 | |
| 1. | I find it easy to use view navigation operation in 3D virtual scene. | 0 | 3 | 7 | 9 | 1 | 3.40 |

| | | | | | | | |
|----|---|---|---|---|----|---|------|
| 2. | I find it easy to manipulate 3D blocks in 3D virtual scene. | 0 | 4 | 8 | 7 | 1 | 3.25 |
| 3. | I find it easy to change 3D blocks' color and transparency. | 1 | 2 | 9 | 6 | 2 | 3.30 |
| 4. | It takes a short time to learn to use VMW system. | 0 | 1 | 8 | 9 | 2 | 3.60 |
| 5. | I find it easy to use text writing function of multimedia whiteboard. | 0 | 3 | 2 | 9 | 6 | 3.90 |
| 6. | I find it easy to use free-sketching function of multimedia whiteboard. | 0 | 4 | 7 | 7 | 2 | 3.35 |
| 7. | It takes a short time to learn to use multimedia whiteboard. | 0 | 1 | 6 | 10 | 3 | 3.75 |
| 8. | Overall, I find it easy to get VMW system to do what I want it to do. | 0 | 6 | 9 | 5 | 0 | 2.95 |
| 9. | Overall, learning to operate VMW system is easy for me. | 1 | 3 | 7 | 7 | 2 | 3.30 |

SD: Strongly disagree, D: Disagree, U: Unsure, A: Agree, SA: Strongly agree, Ave: Average

Table 4. Corresponded factors of perceived usefulness and ease of use items

| NO. | Factor |
|--------------------|---|
| Usefulness | |
| 1. | Performance for posing/solving geometry question |
| 2. | 3D viewpoint is useful to figure out solution. |
| 3. | Whiteboard presentation enhances effectiveness. |
| 4. | 3D presentation enhances effectiveness. |
| 5. | VMW system is useful to show my solution. |
| 6. | Enjoyment. |
| 7. | Free whiteboard placement is useful to figure out solution. |
| 8. | VMW system is useful to figure out solution. |
| 9. | Make task easier |
| Ease of Use | |
| 1. | View navigation is controllable. |
| 2. | Virtual Manipulation is controllable. |
| 3. | Changing block's attribute is controllable. |
| 4. | Easy to learn VMW system. |
| 5. | Text writing function of whiteboard is controllable. |
| 6. | Free-sketching function is controllable. |
| 7. | Easy to learn whiteboard function. |
| 8. | Easy to become skillful with VMW system. |
| 9. | Easy to use VMW system. |

Content Analysis

The Math teacher posed eight geometry questions in this study. They were all area and volume reasoning problems. The eight questions were divided into two categories, irregular and regular shapes stacking with blocks. In the irregular category, some blocks were employed to build irregular shapes. Since these shapes were not regular, it was neither easy nor straightforward to find the math rules needed to get the answers. Sometime students could re-stack

cubes into regular or near regular shape to find an efficient way to get the answer. In regular stacking questions, blocks were stacked in specific ways so students could use the stacking rule for the solutions. However, if the number of blocks was huge, and if students used a straightforward counting method to get the answers, a great deal of time was required and there was a high probability of mistakes being made.

There were two questions, one regular and one irregular, chosen for content and statistical analysis, which we called question A and B respectively (see Figure 6 and Figure 7). The students' whiteboard contents were analyzed to find their solving strategies (not including revised solutions from the peer review session). To show solving strategies clearly, the description of their strategies and the statistical distribution of correct answers and wrong ones were given. Their solving strategies of question A and B were described in details as follows.

Question A: How can we find the volume and surface area of irregular stacking blocks? In this question, the Math teacher used 19 blocks to create an irregular, three-tiered object. Although the stack had no specific rule, students were expected to use a more efficient way to figure out the answers rather than merely counting.

To determine the volume, more than half students used a re-stacking method to simplify the problem, as shown in Table 4. One of those students got the wrong answer due to mistakes in calculation. The remaining students simply counted the blocks. The first group of students re-stacked the blocks into one-level or multi-level rectangular solids. Four students first calculated the volume of cuboids, and then added the remaining cubes or subtracted missing ones to get their answers, as shown in Figure 6A. Three other students re-stacked all cubes into several one-level rectangles of different sizes and added up the volume of all the new rectangles to get the answer. Five students reorganized the object into one single-layer rectangle and calculated the answer.



Figure 6. Snapshot of question A

The surface area reasoning was more difficult than volume reasoning and most students used some kind of rule to get their answer. As shown in Table 5, there were four students who got wrong answers because of a misconception or errors in calculation. The students who got the right answer efficiently applied a rule related to classifying six surfaces of irregular blocks: six surfaces were divided into three pairs, two surfaces in each pair have the same area. Therefore, the sum of three different area surfaces' areas was first calculated and multiplied by 2 to get the answers. Only five students used a straightforward counting method to determine the surface area of the stack.

Table 5. The distribution of volume solution methods in question A

| Method | Correct | Wrong |
|--|---------|-------|
| 1. Straightforward Counting method | 10 | 0 |
| 2. Re-stacking Method | 12 | 1 |
| 2.1 Multilayer Stack | 7 | 0 |
| 2.1.1. Stack into rectangles with variable sizes | 3 | 0 |
| 2.1.2. Stack into cuboids | 4 | 0 |
| 2.2. Single-layer Stack | 5 | 1 |
| Total | 22 | 1 |

Table 6. The distribution of surface area solution methods in question A

| Method | Correct | Wrong |
|--|---------|-------|
| 1. Straightforward Counting method | 3 | 2 |
| 2. Calculating three surfaces area and multiplying 2 | 16 | 1 |
| 3. Misconception | 0 | 1 |
| Total | 19 | 4 |

Question B: How do we find the volume and surface area of pyramid? To study how students figured out the rules to find the volume and surface area of a regular stacking shape, the Math teacher stacked a seven-level pyramid. Then she asked students to find its volume and surface area.



Figure 7. Snapshot of question B

Most students used partition strategies to find the rule and simplify the computation to determine the volume, as shown in Table 6. Students using a horizontal partition strategy divided the pyramid into seven square levels and easily calculated the volume of each one. The total volume was then determined by adding the volume of the levels together. However, one student employed a vertical partition strategy, decomposing the pyramid into vertical slices, and then adding up the volume of all the slices to get the answer (in Figure 7). The results showed the versatility of the VMW system, as it provided the students with the flexibility to explore new ideas, and gave the teacher ways to understand and promote the way the students' thinking in a geometrical problem solving context.

Table 7. The solution distribution of volume problems in question B

| Method | Correct | Wrong |
|--|---------|-------|
| 1. Give up | 0 | 4 |
| 2. Horizontal partition | 15 | 2 |
| 2.1. Summing all levels | 12 | 2 |
| 2.2. Specifying extra blocks in next level | 3 | 0 |
| 3. Vertical partition (Outward extension) | 1 | 1 |
| Total | 16 | 7 |

In surface area portion of the problem only half of the students got the correct solution, as shown in Table 7. Seven students found the rule that the top and bottom surface belonged to the same dimension and their surface areas were equal (bottom surface area multiplied by 2) and four other faces' surface areas (the front, back, right and left side of the pyramid) were equal (one face surface area multiplied by 4). The others used a method similar to the one used to answer question A to figure out the surface area. Even pyramid is regular in shape. But question B seemed to be more difficult than the question A, because the pyramid of the question B had a large number of blocks. Almost half students did not get the correct answer for volume and surface area.

Table 8. The solution distribution of surface area in question B

| Method | Correct | Wrong |
|---|---------|-------|
| 1. Give up | 0 | 5 |
| 2. Misconception | 0 | 6 |
| 3. Specifying each faces' surface area | 11 | 1 |
| 3.1. Bottom surface area multiplied by 2+ one side surface area multiplied by 4 | 7 | 1 |
| 3.2. Summation of top, left and front surface area multiplied by 2 | 4 | 0 |
| Total | 11 | 12 |

Asynchronous Collaboration

During the activity, teachers did not only ask students to write their own solutions but also encouraged them to comment on the solutions provided by their classmates. As stated earlier, with the VMW system, the multimedia whiteboard can be used to represent abstract ideas in Virtual 3D scene, and allows teachers and students to communicate and share ideas through an asynchronous discussion board. Some examples of asynchronous collaboration between students are described below.

Figure 8 shows one example regarding mathematical discussion. Although student A gave correct answers to the volume and surface area questions, students B and C gave critiqued the work and asked student A to find a way to simplify the Math calculation and to describe the physical meaning of the solution. In Figure 9, student A gave the

incorrect answer to the problem of surface area, and student B responded by pointing out what was wrong, after which student A revised his answer. Figure 10 gives another example of the way students critiqued each other's work and revised their own answers. Comments by Student B reminded student A that he had made some mistakes in calculating the volume, whereupon Student A corrected his answer and gave a clearer description of how he solved the question.

The ability to share their ideas, and to affirm, refute and respond to the work of their peers, as facilitated by the VMW system, helped the students to clarify their thinking about mathematical problem solving. With the asynchronous discussion board and teacher's encouragement, most students were willing to use the system to describe their ideas and solutions clearly and thoroughly. Through this kind of interactive communication, more correct answers and meaningful responses to others' comments or queries were derived.

每個小正方體的邊長為1cm，請問此圖形的體積與表面積各是多少？

1. Teacher posed a geometry question:

Each cube side is 1 cm. Please figure out the volume and surface area of stacked blocks.

2. Student A answered the question:

Volume:
 $4 \times 4 = 16$, $16 + 3 = 19$, A: 19 cm^3 . I used re-stacking method to solve this problem. I moved some blocks down for transforming shape into a $4 \times 4 + 3$ size then got the answer is 19 cm^3 .

Surface area:
 $8 + 9 = 17$, $17 + 9 = 26$, $26 + 8 = 34$, $34 + 11 = 45$, $45 + 11 = 56$, A: 56 cm^2 . I rotated the view and watched six sides of surface area for summing.

3. Student B gave critique:

You didn't find the rule of surface area, please clarify your answer more clearly!

4. Student C gave critique:

You did not point the equation for each side, please give clear description. You may use Y, Z, X axis to represent your answer.

5. Student A revised his surface area solution for responding critiques:

Its front and back sides are all 8 cm^2 .
 Its up and down are all 11 cm^2 .
 Its left and right are all 9 cm^2 .
 Because surface area is symmetric, therefore we must multiply them by 2.
 $8 \times 2 + 11 \times 2 + 9 \times 2 = 56 \text{ cm}^2$.

Figure 8. Student responded others' critiques to give clearer answer

Figure 9 illustrates a sequence of four screenshots from a geometry problem-solving task, showing a student's response to a critique and a subsequent revision.

Top Screenshot (Initial Problem):

Each cube side is 1 cm. Please figure out the volume and surface area of stacked blocks. Please give your answer in detail.

1. Teacher posed a geometry question:

Each cube side is 1 cm. Please figure out the volume and surface area of stacked blocks. Please give your answer in detail.

Second Screenshot (Student A's Initial Answer):

Volume:

1. $4 \times 3 \times 1 = 12$, A: 12 立方公分

運用搬移

Surface area:

2. $1 \times 1 = 1$, $1 + 3 + 3 = 7$, $3 + 2 + 1 = 6$, $6 \times 3 = 18$, $1 + 2 + 3 = 7$, $18 + 7 + 7 = 32$, A: 32 平方公分

運用旋轉

Third Screenshot (Student B's Critique):

3. Student B gave critique:

Your answer is wrong. It should be 36 cm^3 . Moreover, $3 + 2 + 1 = 6$, $1 + 2 + 3 = 7$. Are they equals?

錯了... 答案應該是 38 平方公分, 而且... $3 + 2 + 1 = 6$, $1 + 2 + 3 = 7$, 兩個一樣的題目,

Bottom Screenshot (Student A's Revision):

2. 修正

$1 + 3 + 3 = 7 \times 2 = 14$, $3 + 2 + 1 = 6 \times 4 = 24$, $14 + 24 = 38$, A: 38 平方公分

把 1 面的面積算出來再成跟它一樣面積的面的數

2. Revision:

$1 + 3 + 3 (\times 2) = 7 \times 2 = 14$, $3 + 2 + 1 (\times 4) = 6 \times 4 = 24$, $14 + 24 = 38$. A: 38 cm^3 . I figured out all sides of surface area first. Then multiply them with the number of same sides.

Figure 9. Student responded others' critique to revise his answer

互論：體積與表面積 (三)

每個小正方體的邊長為1cm，請問此圖形的體積與表面積各是多少？

1. Teacher posed a geometry question:

Each cube side is 1 cm. Please figure out the volume and surface area of stacked blocks.

2. Student A gave his answer in the beginning:

Volume:
 $4*4+2*2 = 16+4 = 20$
 I used re-stacking method to solve this problem.

Surface area:
 $8*2+9*2+11*2 = 2*(8+9+11) = 2*28 = 56$
 A: 56cm^2

3. Student B gave critique to volume answer:

Your answer is wrong. It is possible that you made some mistakes. If you are carefully that you can figure out correct answer. Moreover, your answer is not clear. It is better that you give more clear description.

4. Student B gave critique to surface area answer:

Your answer is correct, but you didn't give any description to show how you get answer. You should give more description to clarify your answer.

5. Student A revised his answers to respond critiques:

Volume:
 $4*4+3 = 19$, I re-stacked blocks into a $4*4$ cuboid.

Surface:
 Observe blocks from front, left and up view points.

從前、左、上看

Figure 10. Another example to show student responded others' critique to revise his answer

Conclusions

In this paper, the *Virtual Manipulatives* and *Multimedia Whiteboard* system was proposed to promote a multi-representative construction model to help solve geometry problems. The proposed system was also evaluated with using a perceived acceptance questionnaire, and the results showed that most of subjects considered the system to be useful and easy to use, the researchers having used questionnaires to assess the usability and friendly of proposed system. Making the system even more user-friendly will be a major improvement in the next generation of the system.

Students' solutions were analyzed to determine how they used our tools to solve geometry problems in VMW system. The result showed that more than half of the subjects relied on partition and stacking methods to find the solutions. Meanwhile, versatile approaches to solve geometry problems were also found in this study, indicating that the VMW system could provide more flexible thinking than paper and pencil activities or even manipulation of actual physical objects to allow students to reach their full potential in understanding and solving geometry problems. As previously mentioned, recent literature shows that 3D simulations have invaluable potential for education and promising new directions for study were found as our study sought to enhance geometrical learning by integrating the multimedia whiteboard and Virtual Manipulatives in the VMW system.

For future research, the researchers will include the technology of pattern recognition to classify students' manipulation automatically or semi-automatically and try to find its relationship with the solving strategies, or perhaps study other issues such as the role of gender in problem solving. Although it is difficult to probe mysterious depths of the human mind, it is possible to discover the processes involved in cognitive operations by observing and analyzing the behaviours and verbal expressions of people engaged in intellectual activity (Ashcraft, 2001). Therefore, determining correlations between manipulation and problem solving strategies is helpful in the investigation of how children learn geometry concepts.

Moreover, the authors consider the multi-representative construction model to be a generalized concept. The combination of Virtual Manipulatives and Multimedia Whiteboard design put multi-representation and Constructivism into practice. It can be applied not only to geometry problem solving but also to other domain of learning. Since the VMW system provided a forum for discussion, it allowed teachers and students to pose and solve questions and to share ideas, actively engaging the students in the learning process. We can extend such a model to Internet users so they could use the whiteboard to share ideas and to work collaboratively with 3D model manipulation. It could also be useful in the promotion of product design, game playing and advertising, because useful suggestions from users around the world can be collected, analyzed and used in a variety of ways. Researchers plan to design more 3D models and manipulation widgets to support such endeavor, and to extend their design into various applications and to verify its effectiveness in future studies.

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Design and Implementation of an Object Oriented Learning Activity System

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ABSTRACT

With the development of e-learning technology, many specifications of instructional design have been proposed to make learning activity sharable and reusable. With the specifications and sufficient learning resources, the researches further focus on how to provide learners more appropriate learning activities to improve their learning performance. In this paper, we aim to propose a model which can explicitly represent the knowledge of the mechanism to adapt both the learning activity navigation and content presentation according to learners' knowledge of concepts. In our proposed model, each learning unit object contains the learning items and the related concepts, which can be used to perform adaptive content selection, and the sequencing control of these learning unit objects can be explicitly represented as a directed graph to improve the understandability. Based on the learning sequencing graph, an Object Oriented Learning Activity system is implemented and used to design and perform the learning activity of Scaffolding Instruction, named "*The evaporation, condensation and boil of water*". The Evaluation results show that teachers can effectively design an adaptive learning activity based on concept and misconception hierarchy and the designed learning activity can really improve learners' learning efficacy by the OOLA system.

Keywords

E-Learning System, Adaptive Learning Activity, Graphic Model, Object Oriented Concept

Introduction

With the growth of Internet, e-learning has been globally accepted for making learners conveniently study at any time and any location. In recent years, in order to share and reuse learning resources among different e-learning systems, several standards, such as IMS (IMS 2001), IEEE LOM (IEEE 2002), SCORM (ADL 2004), AICC (AICC 1989) and ARIADNE (ARIADNE 2004) have been proposed. Moreover, Open Knowledge Initiative (O.K.I. 2007) was proposed, based on the concept of service oriented architecture (SOA) to define open, extensible service architecture and the inner components of E-learning platforms, so the modern learning management system can integrate diverse learning services to provide comprehensive learning activities. Based on these specifications, learning contents and services can be managed as learning objects for reusing and assembling. With the sufficient learning resources, the researches then focus on how to provide learners more appropriate learning activities to improve their learning performance.

Concept is an established framework of understanding an objects, events, or processes (Klausmeier 1979). The theory of Meaningful Learning, proposed by (Ausubel 1968), describes that the new knowledge must be constructed based on the learners' prerequisite knowledge, named superordinate concept. (Gagne 1985) also suggested that prior knowledge is the necessary internal condition of learning. Thus, how to provide meaningful learning activities according to learners' ability of concepts is an important and challenging issue to improve learning efficacy.

(Sleeman and Brown 1982) introduced the intelligent tutoring systems (ITS), which incorporate artificial intelligent technology to adapt learning sequence to improve learners' learning performance. (Brusilovsky and Pesin 1998) defines two ways of adaptation in adaptive hypermedia: adaptive presentation to adapt the learning contents and adaptive navigation support to adapt the learning path to the knowledge level of learners. An adaptive learning system can separately maintain the two kinds of knowledge to facilitate maintaining and reusing previous design. Besides, how to make the internal learning objects in ITS reusable and sharable is also an important issue (ADL 2004).

Bayes Nets, based upon statistic methods (Mislevy, Almond et al. 1999; Desmarais and Gagnon 2006), have been used to decide adaptive learning sequence, but they are difficult to incorporate domain expertise of teachers for the

adaptive learning. Sequencing and Navigation in SCORM 2004 (ADL 2004) and Learning Design (IMSLD 2003) are the popular specifications to design adaptive learning activity, so many researches aimed to propose different models and authoring tools to ease the designing and authoring. Among these researches, using graphic models for adaptive learning activity design is an important direction, because teachers can design the complex adaptive sequence by the intuitive graphic representation. (Martens 2005) applied the definition of finite automata with learner model to describe adaptive learning sequence and presentation. (Chen, Huang et al. 2005; Huang, Chen et al. 2008; Wang, Huang et al. 2008) used Dynamic Fuzzy Petri Nets to represent the learning paths and remedial learning contents. (Chang, Hung et al. 2003; Lin, Chang et al. 2005) applied Inference Diagram to describe the courseware diagram and support the evaluation of learners' learning performance. These models can effectively reduce the design cost of adaptive learning activities. (Martens 2005) further defined the learner model, transition function, and show function to describe the adaptive navigation support and presentation, but did not mention about how to determine the learning sequence and contents according to learners' knowledge. It implies that teachers have to design the transition function and learner model by themselves in the real system. The model of Dynamic Fuzzy Petri Nets (Chen, Huang et al. 2005; Huang, Chen et al. 2008; Wang, Huang et al. 2008) and Inference Diagram (Chang, Hung et al. 2003; Lin, Chang et al. 2005) can determine the learning sequence only using single examination score, which can not represent the learners' knowledge of concepts if multiple concepts could be learned in this activity.

To cope with the above issues, our idea is to explicitly represent the knowledge of the mechanism to adapt both the learning activity navigation and content presentation according to learners' knowledge of concepts. Thus, we propose a novel model, named Learning Sequencing Graph (LSG), which includes global scope and local scope to describe the adaptive navigation support and adaptive contents presentation, respectively. In the global scope, the adaptive learning sequence is explicitly represented as a directed graph to improve the understandability, where the edges in the directed graph describe constraints of multiple concepts to guide learners to the appropriate learning path according to their knowledge of concepts. Under the global scope, the learning unit objects are defined within their own local scope, named learning unit scope. In learning unit scope, the concept matrix is defined to describe weights of concepts in learning items. These concept weights can be used to select the presented learning items to achieve adaptive presentation, and in the exam, the learners' concept knowledge can be evaluated according to the concept weights of the test items. Thus, adaptive navigation support and adaptive presentation based on learners' concept knowledge can be fully supported by the intuitive design in global and local scopes of LSG. The adaptive learning sequence, referring to multiple concepts, is more flexible to fulfill the needs of various pedagogical approaches. Moreover, because concepts are the interfaces between learning items and adaptive learning sequence, the learning sequence design does not have to be modified when replacing learning items or adding new learning items.

Accordingly, we design and implement an Object Oriented Learning Activity System (OOLA system), with a graphical authoring tool, which can assist teachers to design adaptive learning activity, and a web based learning system, which can steer learners learning using a rule inference engine. Therefore, teachers do not need to concern with the detailed implementation of the whole adaptive learning system, and they just need to design learning sequences and determine the presentation information using a graphical interface, and then the learning activity based on LSG can be automatically transformed to a rule class (Lin, Tseng et al. 2003), which can be conducted by the rule inference engine.

We compare the features of adaptive learning model, with SCORM SN, IMS LD, LAMS, and the related graph based learning models. The result shows that learning sequencing graph is better to represent adaptive learning. Moreover, we use OOLA system to design a learning activity "*The evaporation, condensation and boil of water*" based on Scaffolding Instruction, which can guide learners to study according to their prior knowledge and help learners correct their misconceptions. The teachers were also invited to evaluate the authoring effectiveness of OOLA System, and the result shows that the OOLA System can help teachers to construct a correct adaptive learning activity easily.

Related Work

In this section, ADL SCORM, IMS LD, LAMS, and the related graph based learning model are introduced.

SCORM (Sharable Content Object Reference Model)

SCORM, proposed by the Advanced Distributed Learning (ADL) organization in 1997, is one of the most popular standards for learning contents. The SCORM specification is a composite of several specifications developed by international standards organizations, including IMS (IMS 2001), IEEE LOM (IEEE 2002), SCORM (ADL 2004), AICC (AICC 1989) and ARIADNE (ARIADNE 2004). In a nutshell, SCORM is a set of specifications for developing, packaging and delivering high-quality education and training materials whenever and wherever they are needed. The advantages of SCORM-compliant courses are reusable, accessible, interoperable, and durable.

In SCORM 2004, the Sequencing and Navigation (SN), referred from the Simple Sequencing Specification (IMSSS 2003) of IMS, applies sequencing rules, formatted as “*if* <condition set> *Then* <actions>” and navigation controls to the tree nodes of the activity tree, where the learning resources are linked to its leaves. As shown in *Figure 1*, “Organization”, “Item”, and learning resources, contained in an activity tree, are the tree’s root, internal nodes, and leaves, respectively. The learning activity will start from the root “Organization” to control the navigation and learning sequence of the children nodes, and then navigate the descendant nodes, Item₁, Item₁₋₁, resource₁, Item₁₋₂, resource₂, Item₂, Item₂₋₁ in the sequence of left-to-right traversal, where the navigation sequence might be altered according to the firing of the attached sequencing rules, e.g., Sequencing rule₁ will be triggered when Item₁ is reached to change the default navigation sequences, such as skipping child nodes, retry the sub-tree.

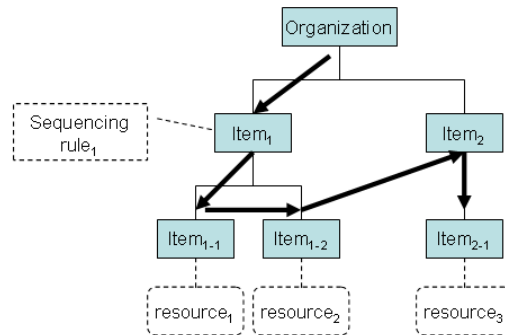


Figure 1: The sequencing control of SCORM SN

IMS Learning Design Specification (LD)

The IMS Learning Design Specification (LD), which was firstly called Educational Modeling Language (EML) and proposed by Open University of the Netherlands, integrates learning contents, QTI test items (QTI 2001), and several predefined learning applications, Send-mail, Conference, monitor, and index-search, into the design of learning activities. These learning resources need different design to work cooperatively; pure learning contents can be linked by URL or files, the test outcomes of QTI test items must have the corresponding properties defined in LD, and the learning applications all have different definitions in LD, which make the modification of learning applications difficult.

An example of sequencing control in LD is shown in *Figure 2*, where the learning activity starts in Play₁, and then the internal act, Act₁₋₁, is fired to enter the Learning Activity₁₋₁, and the contained learning resource, Resource₁₋₁, would be provided to the learner. After finishing Learning Activity₁₋₁, Act₁₋₂, Activity Structure₁₋₂ will be fired, and the sequence of activities, Learning Activity₁₋₂₋₁, Support Activity₁₋₂₋₂ with the corresponding learning resources, Resource₁₋₂₋₁, Resource₁₋₂₋₂, contained in Activity Structure₁₋₂ will be fired subsequently. Then, Play₂ is reached and the internal components, Act₂₋₁, Learning Activity₂₋₁, and Resource₂₋₁ will be triggered. Besides, the Condition Rules and Notification₁ are defined to show or hide some activities under some defined conditions. The sequencing control methods provided by IMS LD have various structures, such as linear sequence, if-then rules, and skip operations, whose complex structures definitions are too difficult to describe the pedagogical approaches.

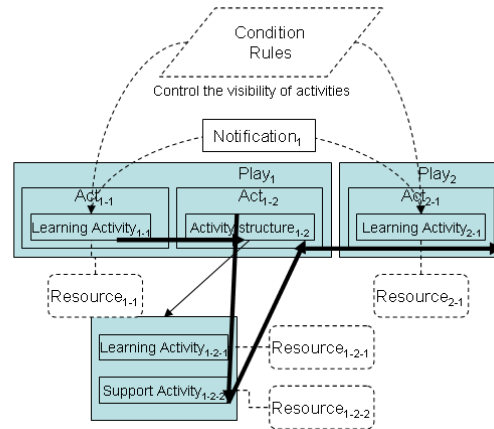


Figure 2: The sequencing control of IMS LD

The authoring system of adaptive learning activity

There are many authoring tools are developed to construct the IMS LD compliant learning activity: Reload (Reload 2004) and CopperAuthor (CopperAuthor 2004) are the low-level tabular LD editors, so only the engineers and experts can use them easily. ASK-LDT (ITI-CERTH, n.d.) can construct only simple learning sequences, because only limited LD features can be supported. Although MOT+LD (Paquette, Léonard et al. 2006) is a graphical learning design editor, the teachers, without the knowledge of IMS LD, are still difficult to construct a learning activity. Collage (Hernández-Leo, Villasclaras-Fernández et al. 2006) uses the formulated patterns (CLFPs) to structure the learning activities according to pedagogical theories, but new patterns cannot be constructed.

The Learning Activity Management System (LAMS) (LAMS 2004) can be used to design a customized collaborative learning activity, where the teacher's environment can monitor the learning status of students. Since only linear learning sequence can be designed by LAMS, the learning activity, designed by LAMS, cannot support adaptive navigation.

The graphic model of adaptive learning activity

Some graphic models are proposed to ease the adaptive learning sequence design: (Martens 2005) applied an extended definition of finite automata to describe adaptive learning sequence and presentation. A learner model, including the profile and knowledge, is defined to record the learner's expertise and learning paths of various learning activities. The transition function can provide adaptive navigation support according to the learners' actions, and the function of content selection can determine the learning contents based on the learner model to achieve adaptive presentation. The model can provide adaptation of both navigation support and presentation, but, since the detailed definitions of learner model, transition and content selection functions were not given, the problem of how to determine the adaptation based on learners' knowledge of concepts is unsolved.

(Chen, Huang et al. 2005; Huang, Chen et al. 2008; Wang, Huang et al. 2008) used Dynamic Fuzzy Petri Nets (DFPN) to represent the behavior of tutoring agent, where the learning activity contains a main learning sequence. After a post test, the remedial learning contents can be shown if the score of test is lower than the threshold. This model can provide adaptive navigation support according to the single test score, but the presented contents are static in each learning unit.

(Chang, Hung et al. 2003; Lin, Chang et al. 2005) applied Inference Diagram to describe the courseware diagram and support the evaluation of learners' learning performance. The learning sequence of each learner can be various with different score range after an examination. Similar to the researches of DFPN, adaptive navigation support is only based on single test score, and the presented contents in each learning units are also static.

Table 1 summarizes the discussion and shows the comparison of four major functionalities: Adaptive Navigation Support, Adaptive Presentation, Concept-based Adaptation, and Graphic Model.

Table 1: Comparison of Adaptive Navigation Support, Adaptive Presentation, Concept-based Adaptation, and Graphic Model

| | Adaptive Navigation Support | Adaptive Presentation | Concept-based Adaptation | Graphic Model |
|--|--|--|---|---|
| SCORM (ADL 2004) | Use Sequencing Rules to control learning sequence | Use Sequencing Rules to control content selection | Use Objectives and sequencing rules to perform adaptation | Not for authoring |
| IMS LD (IMSLD 2003) | Use rules to control learning sequence | Use rules to control learning sequence | Use property with rules to perform adaptation | Not for authoring |
| LAMS (LAMS 2004) | Only static learning sequence | Only static contents | no adaptation | Use a flow chart to represent learning sequence |
| Extended Finite Automata (Martens 2005) | Use transition function to control learning sequence | Use content selection function to select learning contents | No clear definition of concepts in learner model and adaptation mechanism | A graph of finite state machine |
| Dynamic Fuzzy Petri Nets (Huang, Chen et al. 2008) | Dynamically provide remedial learning contents | Provide static learning contents in each learning unit | Only single test score is referred to perform adaptation | A graph of Petri nets |
| Inference Diagram (Chang, Hung et al. 2003) | Dynamically select learning sequence | Provide static learning contents in each learning unit | Only single test score is referred to perform adaptation | A graph of inference diagram |

Object Oriented Learning Activity System

Based on the encapsulation concept of Object Oriented Methodology, the learning unit scope is defined to enhance the reusability under the global scope, in which the design of presentation, learning items, and the weight of corresponding concepts are encapsulated in the learning unit object, and the sequencing controls of a learning activity are explicitly represented as a directed graph to enhance the understandability, where the vertices are these learning unit objects and the edges are associated with the sequencing control rules. The learning sequencing graph of the designed learning activity can be used to automatically generate a rule class, which can be easily applied to control the learning sequence.

Based on learning sequencing graph, an Object Oriented Learning Activity System (OOLA System), including the designing and executing phases, is implemented, as shown in Figure 3. In the designing phase, an adaptive learning activity can be designed via the graphical authoring process to help teachers easily integrate various learning resources, provided by learning resource repositories, and a rule class generating method is also proposed to generate the rule class of learning sequencing controls. In the executing phase, the learning sequencing graph and the rule class are used in rule based adaptive learning method to conduct an adaptive learning to learners.

In the OOLA system, three kinds of learning resource repository are provided: learning content repository can retrieve and display SCORM compliant learning contents, test item bank can provide test items and perform examination, application program repository contains the registration of learning services, which are provide by other learning systems and can be executed and communicated via web services.

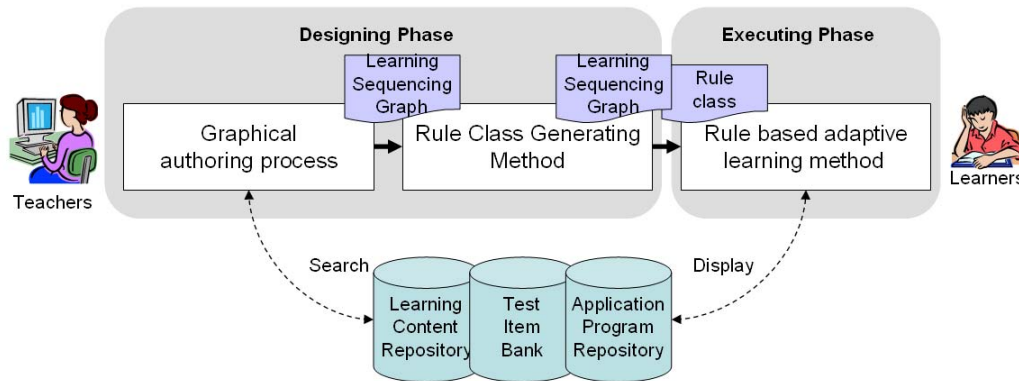


Figure 3: Designing phase and executing phase in OOLA System

Figure 4 illustrates the flowchart of rule based adaptive learning method. After the rule class and learning sequencing graph are loaded into the rule base, the starting learning unit object of the learning sequencing graph is fired. The learning items, included in the fired object, will be provided to learners using a proper display interface according to the type of the learning unit object. Since then, the inference process will be triggered by learners' learning status information, including the latest learned learning unit name and concept scores, to find the next object until the final object is reached.

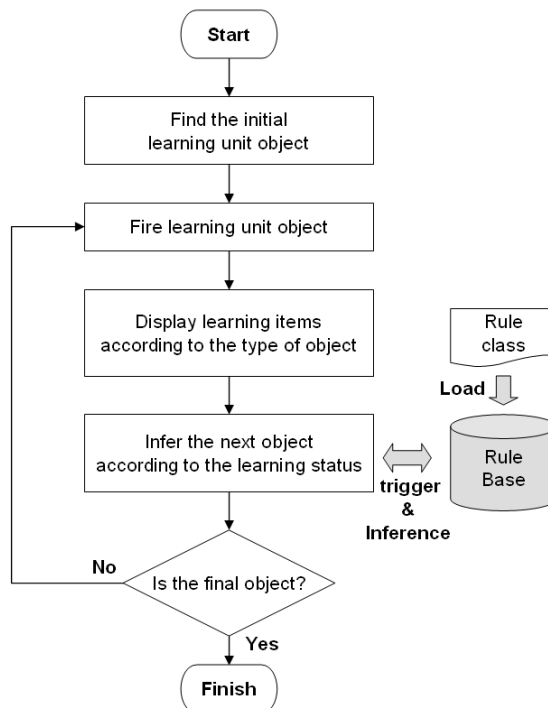


Figure 4: Flowchart of Rule based adaptive learning method

Definitions of Learning Sequencing Graph

The vertices and edges in the learning sequencing graph represent learning unit objects and learning sequencing controls, respectively. A vertex contains a set of learning items associated with the weights of corresponding concepts, which are defined as the concept matrix. There are three types of vertex in the matrix: learning content activity (N_{LA}) contains learning items from learning content repository, learning application activity (N_{AP}) contains learning services registration from application program repository, and examination activity (N_{EA}) contains test items from test item repository. Each vertex also contains the time and duration limit to control the time segment of the learning activity. In order to skip the unnecessary learning items, which are already understood by the learner, the learner's understanding ratio (ur_k), which means the understanding ratio of handling all the concepts contained in the learning item $item_k$, and the learning items skipping threshold (t_skip), used to judge if $item_k$ can be skipped, are defined. A sequence of edges, with associated sequencing control rules, from sources to targets represent legal learning paths of the learners, where a sequencing control rule can contain a set of constraints to determine whether the learner can go to the next unit along the edge or not according to the learners' ability of specific concepts.

Definition 1: Learning Sequencing Graph (LSG)

LSG = (C, V, v_0 , F, LM, E), where

1. **C** = { c_1, c_2, \dots, c_m } is a finite set of concepts.
2. **V** = { v_1, v_2, \dots, v_n } is a finite set of nodes which represent the learning unit objects of a learning activity, where $v_i = (type_i, M^i, duration_i, time_i, t_skip_i)$.
 - $type_i \in \{N_{LA}, N_{AP}, N_{EA}\}$.
 - M^i is a concept matrix, where M^i_{jk} means the weights of concepts c_j in $item_k$, $0 \leq M^i_{jk} \leq 1$.
 - **duration_i** $\begin{cases} > 0, \text{ the duration of } v_i \text{ in minutes.} \\ = 0, \text{ ignore duration limitation.} \end{cases}$
 - **time_i** $\begin{cases} > 0, \text{ the leading time of } v_i \text{ in minutes.} \\ = 0, \text{ start immediately when learner reaches } v_i. \end{cases}$
 - t_skip_i is the threshold of the understanding ratio (ur_k) to let learners ignore the learning items, if the contained knowledge is already handled.

$$\begin{cases} t_skip_i \leq ur_k, item_k \text{ can be ignored.} \\ t_skip_i > ur_k, item_k \text{ will be provided.} \\ t_skip_i = \infty, \text{ all learning items will be provided.} \end{cases}$$
3. $v_0 \in V$ is the initial vertex of LSG.
4. **F** $\subset V$ is a finite set of final vertex.
5. **LM_x** = { $cs^x_1, cs^x_2, \dots, cs^x_m$ }, is a learner model of learner x, where cs^x_i is the learner's ability about the concept c_i .
6. **E** $\subseteq V \times V$ is the finite set of directed edges, and $\forall e_{ij} \in E$, e_{ij} is a directed edge from v_i to v_j , and the attached constraints are defined as cst_{ij} .
 - **cst_{ij}** $\subseteq \{constraint_1, constraint_2, \dots\}$ is a subset of constraints.
 - **constraint_m** = (cs, op, α) is a constraint of concept score, where
 - **cs** $\in LM$ is a specific concept score.
 - **op** $\in \{>, =, <, \geq, \leq, \neq\}$.
 - **α** is a threshold, $0 \leq \alpha \leq 1$.

The following example is given to illustrate the definition of LSG.

Example 1: A learning activity to provide adaptive navigation support

As shown in *Figure 5*, this learning activity starts at an examination activity v_1 as pretest, containing three test items and two corresponding concepts, where v_1 having no leading time can be learned in 20 minutes, and its learning

items skipping threshold is defined as ∞ to allow all learning items to be provided to learners. After finishing the pretest, if all the concept scores are higher than 0.6, a learning application program v_2 will be fired for learners to discover more knowledge about the concepts; otherwise, a remedial instruction v_3 will be given to improve understanding of the missing concepts.

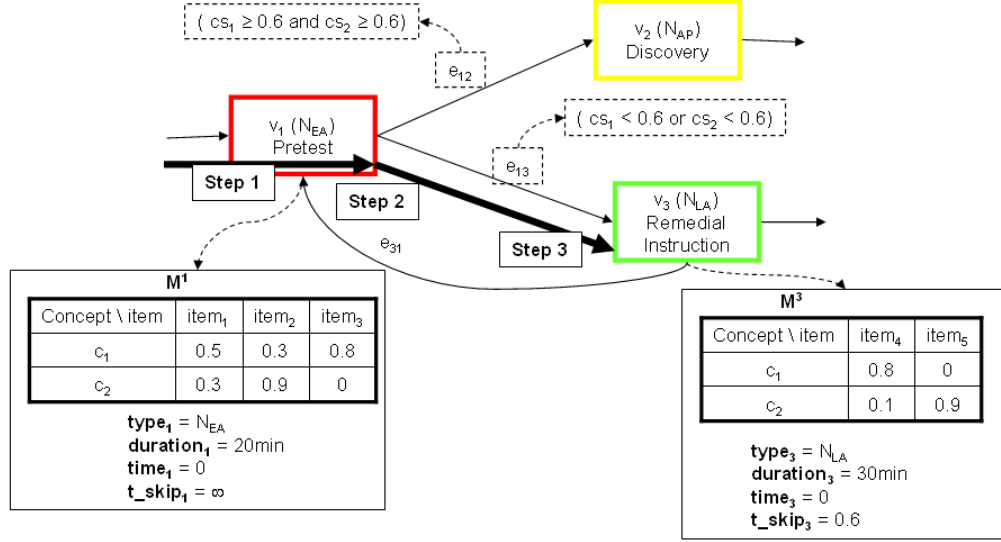


Figure 5: A simple example of learning sequencing graph

Formula of Calculating Concept Score

$\forall v_i, type_i \in N_{EA}$, we can evaluate the learner's **concept score** cs_j of the concept c_j according to the sum of the weights of the passed test items. Let the passing attribute δ_k , which is a Kronecker delta, represents the test result of item_k, where $\delta_k = 1$ if the learner passed this test item, and $\delta_k = 0$ if s/he failed.

$$The \text{ formula to calculate concept score of concept } c_j: cs_j = \frac{\sum_k \delta_k \times M_{jk}^i}{\sum_k M_{jk}^i}$$

Formula of Understanding Ratio (ur_k)

Let ur_k be the average of the weighted concept scores of item_k of all concepts. Concept scores (cs_j), describing the learner's abilities of concepts, are ranged from 0 to 1.

$$The \text{ formula to calculate understanding ratio: } ur_k = \frac{\sum_j cs_j \times M_{jk}}{\sum_j M_{jk}}$$

Example 2: The running process of the learning activity in Example 1

For the learning sequencing graph given in Figure 5, in step 1, the learner firstly enters to the pretest. If s/he passed in item₁ and item₂ but failed in item₃, the concept scores $cs_1 = \frac{0.5+0.3}{0.5+0.3+0.8} = 0.5$ and $cs_2 = \frac{0.3+0.9}{0.3+0.9+0} = 1$. Thus, in step

2, only the constraint rule of e_{13} is fulfilled and s/he may pass the valid edge e_{13} to enter the Remedial Instruction v_3 , where two learning contents, item₄ and item₅, are provided with the understanding ratios

$ur_4 = \frac{0.5 \times 0.8 + 1 \times 0.1}{0.8 + 0.1} = 0.56$ and $ur_5 = \frac{0.5 \times 0 + 1 \times 0.9}{0 + 0.9} = 1$. In step 3, because the t_skip_3 is 0.6, which is lower than ur_5 , the learning content item₅ will be skipped and only item₄ is provided for the learner.

Teachers do not need to consider the detailed rules, definitions of E-learning standards, or system architecture, and only need to design learning activity via a graphical authoring tool, because the learning sequencing graph can be transformed to rules and conducted by a rule based learning system automatically.

Rule Class Generating Method

A learning sequencing graph can be considered as a knowledge object, and several learning activities can be combined to a large scale course. Therefore, we apply New Object oriented Rule Model (NORM) architecture (Tsai, Tseng et al. 1999; Wu 1999; Tsai and Tseng 2002; Lin, Tseng et al. 2003) to represent the guiding rules of learning sequencing graph. Based on Object Oriented Mechanism (Rumbaugh, Blaha et al. 1990; Booch 1991), NORM is a knowledge model of rule base, where the rules about the same knowledge domain are collected into a rule class (RC). Each rule class can include or refer to some other rule classes, and these relevant rule classes will form a set of rule objects (RO), which can be dynamically linked and perform cooperative inference. Therefore, in the rule class generating method, we can generate rule class by the following steps:

1. Generate a fact to record the name of last learned learning unit.
2. Generate a fact to store the name of next learning unit.
3. Generate facts to record the scores of all the concepts.
4. Generate a rule for each e_{ij} to describe: "If the last learned learning unit is v_i and the concept scores satisfy the constraint cst_{ij} , the next learning unit is determined to be v_j ".

Example 3: Generate Rule Class from a learning sequencing graph

The rule class, generated from the learning sequencing graph in *Figure 5*, is shown as Rule Class 1. Firstly, the facts named "*now*" and "*next*" are generated to record the processed vertex and the next learning vertex. According to the C in LSG, the facts, named " cs_1 ", " cs_2 " corresponding to the concepts c_1 and c_2 , respectively, are generated. Finally, the rules are generated according to the edges in E . e_{12} connects from v_1 to v_2 with the constraint of " $cs_1 \geq 0.6$ and $cs_2 \geq 0.6$ ", so the corresponding rule can be generated to describe that if fact "*now*" is v_1 and the constraint of e_{12} is satisfied, then assign v_2 to the fact "*next*". Similarly, the rule of e_{13} can be generated to show the constrained path from v_1 to v_3 .

Rule Class 1: rule class of the simple example in *Figure 5*

Facts:

now: The name of the last learned learning unit.

next: The name of the next learning unit.

cs₁: The score of concept c_1 .

cs₂: The score of concept c_2 .

Rules:

(e_{12}) IF (now = v_1 and ($cs_1 \geq 0.6$ and $cs_2 \geq 0.6$)) THEN assign v_2 to next

(e_{13}) IF (now = v_1 and ($cs_1 < 0.6$ or $cs_2 < 0.6$)) THEN assign v_3 to next

Rule based Adaptive Learning Method

Algorithm 1 uses learning sequencing graph and the generated NORM rule class to conduct an adaptive learning, where inference process can be triggered by the latest learned vertex and concept scores to determine the next vertex to be fired, and learning items, contained in the next vertex, can be filtered, displayed according to the type and the threshold of the understanding ratio of this vertex. In Step 1, the initial vertex is processed in the first iteration. In Step 2.1, the learning items in the processed vertex will be hidden if the learner's corresponding concept knowledge

is good enough to skip these learning items. In Step 2.2, different kinds of learning object units will be executed using different displayer, and if the type of vertex is examination activity, the concept scores will be recorded in learner model (LM) after testing. In Step 2.3, the inference process is triggered to find the next processed vertex according to the current processed vertex and concept scores in learner model. If the inferred vertex is a final vertex, the learning activity will be finished.

Algorithm 1: Rule based Adaptive Learning Method (RAL)

Definition of Symbols:

v_{now} : The vertex, which is processed in current iteration.

Input: The learning sequencing graph and the corresponding rule class

Step 1: Assign v_0 to v_{now}

Step 2: Do while $v_{now} \notin F$

2.1: For each $item_k \in M^{now}$ **in** v_{now}

If understanding ratio $ur_k < t_skip_{now}$ **Then** hide $item_k$

2.2: If $v_{now} \in N_{LA}$ **Then** show learning items in SCORM compliant content displayer

Else if $v_{now} \in N_{AP}$ **Then** show learning items in application program displayer

Else if $v_{now} \in N_{EA}$ **Then** show learning items in test item displayer

 Check answers and calculate concept scores cs_j after finishing the test

 Assign cs_j into LM.

2.3: Trigger the inference process with inputted rule class:

 Set name of v_{now} and cs_j into the facts

 Infer the next learning unit and set into v_{now}

End while

Step 3: The learning activity is finished

Example 4: Apply Rule based Adaptive Learning Method to the simple example in Figure 5

The behavior of rule based adaptive learning method, which is applied to the learning process in Example 2, is shown: In Step 1, the starting vertex, v_1 , is assigned to v_{now} . In the first iteration of Step 2, all learning items of v_1 can be shown because $t_skip_1 = \infty$, and they are shown in test item displayer because $v_1 \in N_{EA}$. After exam, the concept scores $cs_1 = 0.5$, $cs_2 = 1$, and $v_{now} = v_1$ are assigned into the facts and the inferred next learning unit is v_3 . In the second iteration of Step 2, $item_4$ is shown and $item_5$ will be hidden because $ur_5 < t_skip_2$, and then these learning items are shown in SCORM compliant content displayer. After studying the learning unit, the next one will be inferred and iterations will be continued until the final vertex is gotten and the learning activity is finished.

Comparing the Features of Adaptive Learning Model

In Table 2, we compare the features of adaptive learning model, including adaptive navigation support, adaptive presentation, concept-based adaptation, and graphic Model, where ‘O’ means the feature is not difficult to be represented by this model, ‘ Δ ’ means it is moderately difficult to be represented, and ‘X’ means it is very difficult. In SCORM and IMS LD, the adaptive navigation support and adaptive presentation can be fully support, and the concepts can be implicitly defined in the variables, but the two specifications do not have a graphic model for designing. LAMS is a graphic authoring tool, but it can not support adaptive learning design. Extended Finite Automata is a graphic model to represent the adaptive mechanism, but no clear definition of concepts in adaptation mechanism. Dynamic Fuzzy Petri Nets and Inference Diagram are also graphic adaptive learning models, but their single criterion adaptation can not support adaptive navigation and presentation according to learners’ knowledge of concepts. Our proposed LSG is a model of directed graph, where adaptive navigation support and adaptive presentation can be design based on learners’ concepts in global and local scope, respectively, so LSG can perform all the features of adaptive learning model.

Table 2: The comparison table of Adaptive Navigation Support, Adaptive Presentation, Concept-based Adaptation, and Graphic Model

| | Adaptive Navigation Support | Adaptive Presentation | Concept-based Adaptation | Graphic Model |
|---|-----------------------------------|--------------------------|-----------------------------|---------------|
| SCORM(ADL 2004) | O | O | Δ | X |
| IMS LD(IMS LD 2003) | O | O | Δ | X |
| LAMS(LAMS 2004) | X | X | X | O |
| Extended Finite Automata(Martens 2005) | O | O | X | O |
| Dynamic Fuzzy Petri Nets(Huang, Chen et al. 2008) | Δ | X | X | O |
| Inference Diagram(Chang, Hung et al. 2003) | Δ | X | X | O |
| LSG | O | O | O | O |

Design a learning activity of Scaffolding Instruction

We have implemented an OOLA system and invited in-service teachers to design a scientific learning activity, named “*The evaporation, condensation and boil of water*” based upon the concept of Scaffolding Instruction (Raymond 2000). Scaffolding Instruction originates from the concept of “*zone of proximal development (ZPD)*”, proposed by (Vygotsky 1978), which means the distance between what learners can do by themselves and what they can be helped to achieve. The teaching strategy of Scaffolding Instruction provides individualized support, named Scaffolding, based on the learner’s ZPD (Chang, Chen et al. 2002). Thus, it is important to clearly evaluate the learners’ prior knowledge to provide scaffolding in learners’ ZPD. Besides, according to (Osborne and Cosgrove 1983), in the scientific learning about water cycle, some misconceptions are generated easily to confuse learners. These misconceptions can make learning more difficult, so in the adaptive learning activity, we aim to find the misconceptions and provide appropriate remedial instructions.

Before designing the learning activity, the scope of this learning activity was clearly defined in Figure 6. Based on the theory of (Gagne 1992), we organized the related concepts of water cycle in a concept hierarchy, shown in Figure 7, and collected the data of related misconceptions to construct a misconception hierarchy, shown in Figure 8. Accordingly, the knowledge evaluation test items were designed to evaluate the learners’ prior knowledge, and the regular learning contents were constructed to teach all related concepts. In order to help learners find and correct misconceptions, the diagnostic test items and the corresponding contents of remedial instruction were constructed. All the learning sequences were designed as flowcharts and further integrated learning resources to construct an online learning activity in OOLA system. This learning activity can be performed after a regular lecture of water cycle to improve the learners’ learning efficacy.

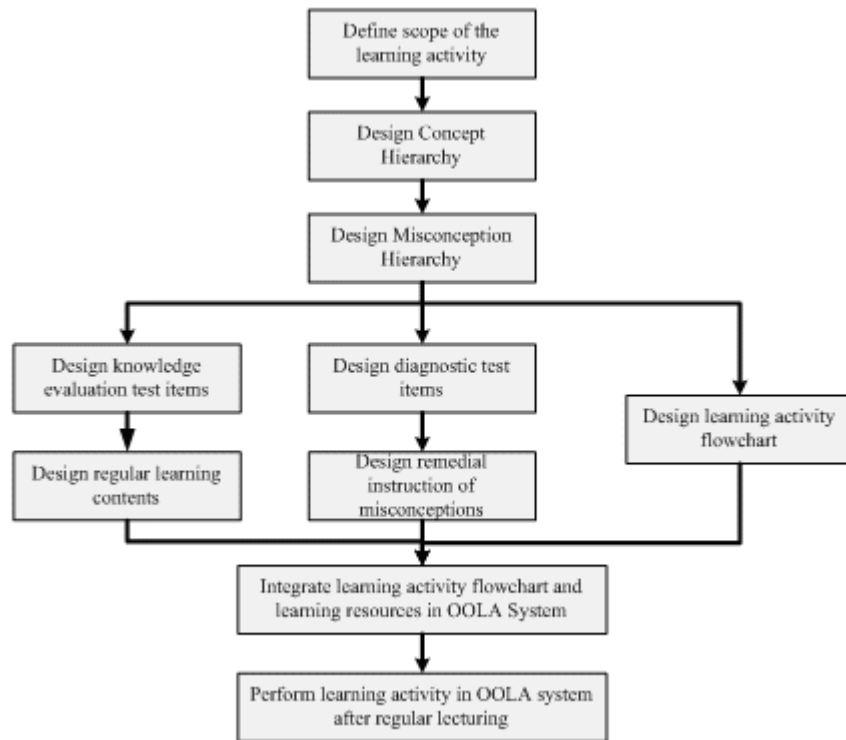


Figure 6: Flowchart of designing a learning activity in OOLA system

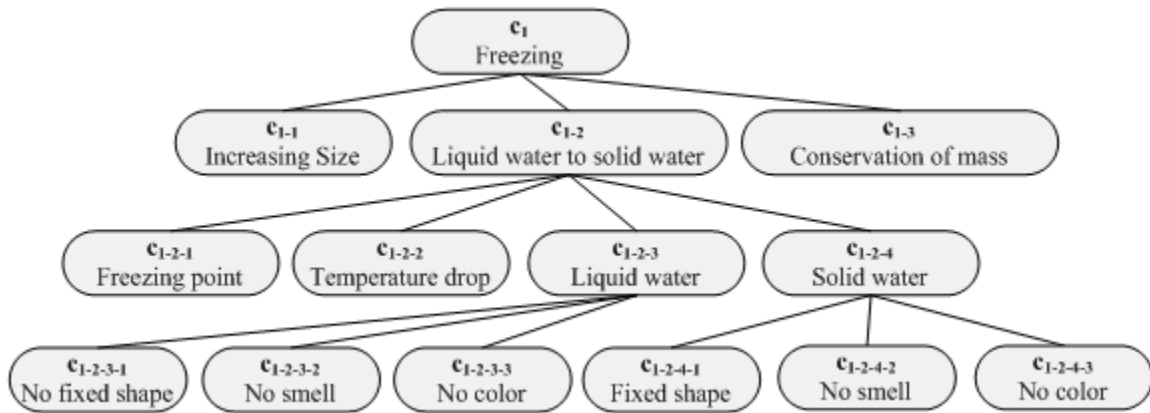


Figure 7: A partial concept hierarchy of freezing in water cycle

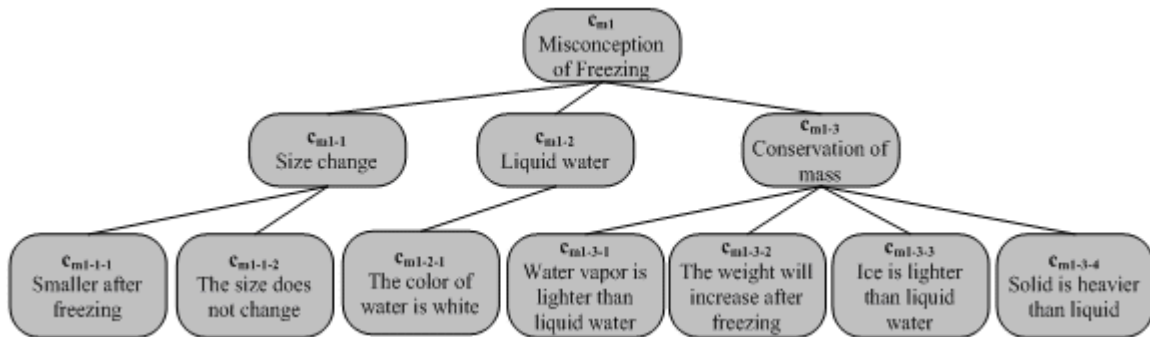


Figure 8: The partial misconception hierarchy of freezing in water cycle

In the strategy of the learning activity, shown in Figure 9, a course introduction is given as an advance organizer (Ausubel 1968), and then a pre test is given to evaluate the prior knowledge of the learner. If the learner has already understood the topic of this learning activity, an activity is provided to enhance the impression. Otherwise, learning contents are provided based on the learner's prior knowledge. After the concept learning, a post test is given to evaluate the learner's learning outcomes, and if any concept still can not be handled, the diagnostic test is used to find the misconceptions, which will be remedied by the remedial instructions.

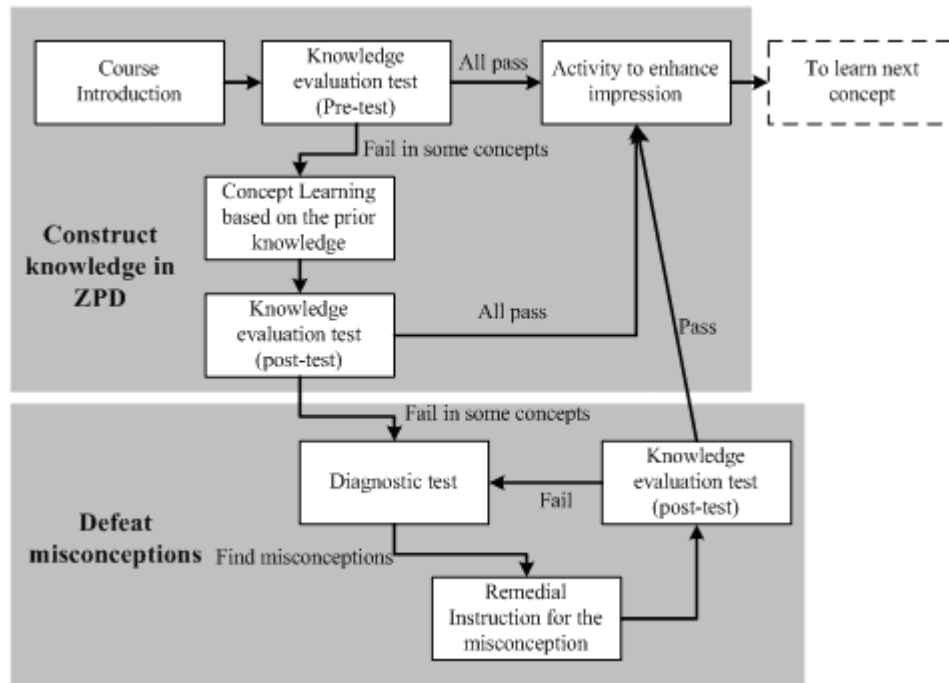


Figure 9: The teaching strategy of the scaffolding instruction with misconception diagnosis

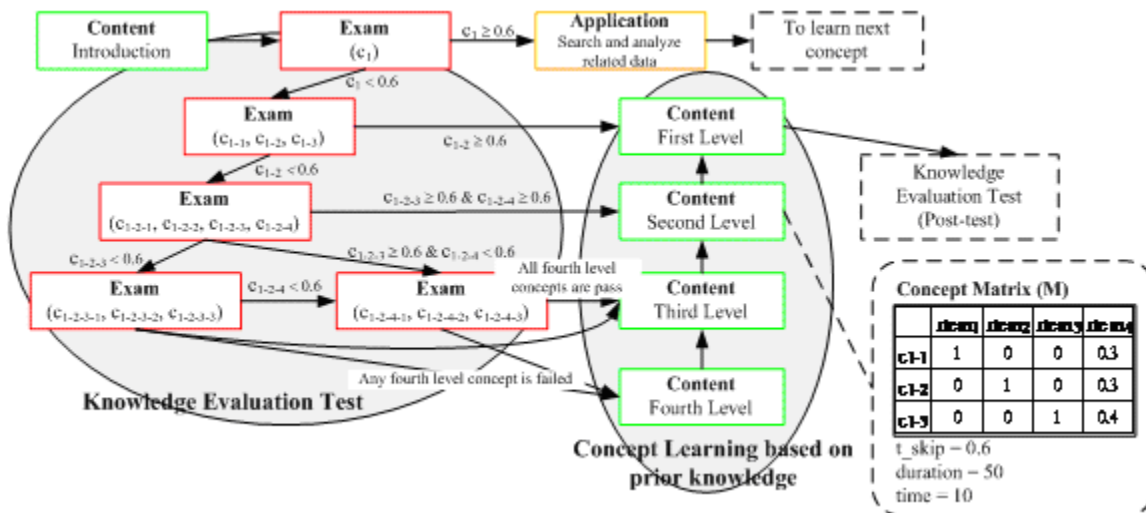
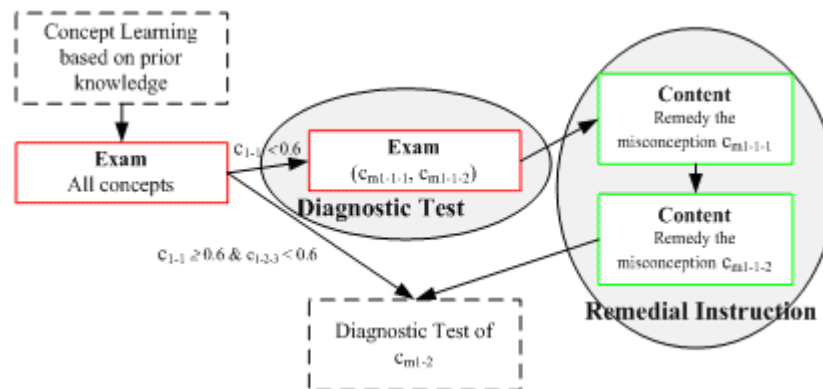


Figure 10: A part of flowchart of learning activity "The evaporation, condensation and boil of water"

Accordingly, as shown in Figure 10, the flowcharts of knowledge evaluation test and concept learning in the learning activity were designed. In knowledge evaluation test, the exam about the most general concept c_1 , named "Freezing", is given to evaluate the overall knowledge of freezing. If c_1 is understood by learners, the learning services of search engine and file-upload service are provided for learners to find related data and upload the reports to teachers.

Otherwise, if c_1 can not be totally understood, the evaluation test will drill down to evaluate the prerequisite concepts c_{1-1} , c_{1-2} , and c_{1-3} in the lower level of concept hierarchy and the rest may be deduced by analogy until the concepts of weak understanding in the lowest level are evaluated. Then, the learning contents will be provided to construct knowledge from the lowest level concepts, evaluated in knowledge evaluation test, to the top level concept. In each learning unit object, the learning contents can be hidden if the learner has already had the knowledge. For example, in the matrix of second level contents, $item_1$ will be displayed only if the score of concept c_{1-1} is lower than 0.6, and the $item_4$ will be shown only if the average score of c_{1-1} , c_{1-2} , and c_{1-3} is very low.



This application shows how to evaluate a learner's prior knowledge based on concept hierarchy by the mechanism of adaptive navigation support in OOLA system. In the concept learning, the adaptive presentation mechanism is performed based on the concept matrix to select the appropriate learning contents according to learner's prior knowledge. Moreover, with misconception hierarchy, the learning activity can perform the corresponding diagnosis and remedial instruction for each misconception. Figure 12 is the screenshot of authoring tool of OOLA system.

Figure 12: Screenshot of the authoring tool of OOLA system

Evaluating the effectiveness of OOLA System in authoring

After questioning with questionnaires, the teachers' comments said that this authoring methodology is effective and easy to use, because designing learning activities in the authoring tool of OOLA system is similar to drawing teaching flowcharts. Moreover, the cost of building learning materials can be largely reduced because all the learning contents can be reused in different learning activities by means of the three kinds of learning resource repositories. In the following, the teachers were invited to evaluate the effectiveness of constructing an adaptive learning activity. The result of the questionnaire is shown in *Table 3*.

Table 3: The questionnaire result of authoring tool in OOLA System

| The main question of questionnaire | Experts' result |
|--|-----------------|
| The teaching flowcharts can satisfy the requirements of pedagogical theories | 86% |
| The three type of nodes in learning sequencing graph can satisfy the requirements of a learning activity | 95% |
| The three type of nodes in learning sequencing graph can model the teaching flowcharts | 90% |
| The learning sequencing graph can satisfy the requirements of pedagogical theories | 87% |

The experimental results show that the teaching flowcharts are easy to design for teachers and satisfy the requirements of pedagogical theories with 86% agreement, and that more than 87% of experts agree that learning sequencing graph can correctly model the teaching flowcharts and satisfy the requirements of the original pedagogical theories. Moreover, according to teachers' comments, converting teaching flowcharts to learning sequencing graph is also easy. The detailed comments are summarized as follows:

OOLA system can facilitate constructing adaptive learning sequence based on pedagogical theory.

- The flexible teaching strategy can be applied in learning activity easily.
- The graphic user interface is intuitive to facilitate the complex authoring task.
- It is better to provide the learning sequence templates for popular teaching strategies.
- The concepts should be managed hierarchically in the system.

OOLA system can facilitate designing remedial instruction to correct learners' misconceptions.

- The comprehensive diagnostic test can be used to evaluate multiple concepts, so the appropriate feedback can be provided by the system.
- The online misconception diagnosis and corresponding remedial instruction can reduce the teachers' teaching cost of giving feedback to students after examination.
- The misconception diagnosis and the following learning contents can drive students to perform self-learning.

OOLA system can facilitate adaptive presentation in learning activity

- It can reduce much designing cost to automatically determine the learning items of remedial instruction based on concept matrix.
- It can also reduce much designing cost to automatically select the test items in diagnostic tests based on concept matrix.

It is easy to replace learning items or modify learning sequence using OOLA system.

- It is convenient to replace and add learning items without modifying learning sequence.
- The learning object units can be used in many learning activity to reduce the design cost.

The system can improve the learning performance

- The learning interface of OOLA system is easy to use.
- OOLA system can drive the low-grade learners to learn more actively and independently.
- The some kinds of multimedia contents can not be displayed in OOLA system.
- In the learning interface, the students should be able to check the whole learning sequence and their learning progress.

Other comments

- It is necessary to add monitor mechanism in the learning system for teachers to understand the behaviors of students.

- OOLA system should add student-to-student and teacher-to-student interaction mechanism for collaborative learning.
- OOLA system should provide the functions of analysis and statistic of learner portfolio to help teachers understand the learners' learning status.

Therefore, we may conclude that the authoring tool of OOLA System can help teachers to construct a learning activity with pedagogical theories easily and correctly, but some functions, such as concept management, learner portfolio analysis, multimedia contents support, and collaborative learning support, are needed to be improved.

The constructed learning activity "*The evaporation, condensation and boil of water*" was also used for 62 students of 5th graders in Taiwan to show that the learning activity, designed by OOLA system, can really improve the learners' learning efficacy. The results show that the learning activity is effective for low-grade students, because the learning activity can help low-grade students find and resolve misconceptions.

Conclusion

In this paper, based on the theory of meaningful learning, we aimed to help teachers design learning activities, which can provide adaptive learning according to learners' knowledge of concepts. Thus, based on the idea of adaptive hypermedia, we proposed a learning sequencing graph (LSG), including the design of adaptive navigation support and adaptive presentation in the global scope and the internal local scope, respectively. In the global scope, the adaptive learning sequence is explicitly represented as a directed graph to improve the understandability. Under the global scope, learning unit objects are defined to encapsulate the design of internal learning items and the related concept matrix in their local scopes. The concept matrix, defining the weights of concepts in each learning items, can be used to select learning items, according to learners' concept scores, to perform adaptive presentation, and evaluate the learners' learning performance of each concept after diagnostic test. In the LSG, the edges describe the constraints of multiple concepts to provide learners adaptive navigation support, and the three kinds of vertex can trigger various learning items, including learning contents, test items, and learning services.

Accordingly, OOLA system was implemented, where a graphical authoring tool is provided to help teachers design LSG intuitively, and the designed learning activity can be transformed to rule classes, which can be used to conduct adaptive learning in OOLA system. Some teachers have been involved in the project of constructing a learning activity "*The evaporation, condensation and boil of water*" based on Scaffolding Instruction, where the learners' concepts can be evaluated in the knowledge evaluation test. After learning, the diagnostic tests and remedial instructions are provided to help learners correct their misconceptions. Finally, the effectiveness of authoring has been evaluated, and the results show that OOLA system can facilitate designing adaptive learning activity with remedial instructions, adaptive learning sequence, and adaptive content selection, based on pedagogical theory.

In the near future, the mechanism of concept ontology will be applied to OOLA system to support more intelligent adaptation of learning sequence and content selection, and more effective concept management. The knowledge based approach will also be applied to analyze learner portfolio to provide teachers better learning status analysis, and provide learners better feedback. Moreover, the types of learning resources will be extended to incorporate the necessary functions of collaborative and cooperative learning.

Acknowledgement

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A Multimedia English Learning System Using HMMs to Improve Phonemic Awareness for English Learning

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ABSTRACT

This paper proposes a multimedia English learning (MEL) system, based on Hidden Markov Models (HMMs) and mastery theory strategy, for teaching students with the aim of enhancing their English phonetic awareness and pronunciation. It can analyze phonetic structures, identify and capture pronunciation errors to provide students with targeted advice in pronunciation, intonation, rhythm and volume. In addition, the paper also applies the mastery learning to effectively help students practice pronunciation of English words and sentences. Finally, this paper adopts a quasi-experimental design and lasting for 12 weeks and 120 third-graders, aged 9-10 years, from an elementary school in Yunlin County in Taiwan. These students were recruited and randomly assigned as the experimental group and the control group, respectively. The former used the MEL system, while the latter received the conventional English teaching. Research data were collected through the Phonemic Awareness Test and the English Achievement Test. The results showed that the experimental group with low phonemic awareness performed significantly better than the control group in the English Achievement Test.

Keywords

Applications in Speech recognition, English pronunciation, Hidden Markov models, Mastery learning, Multimedia learning system

Introduction

Phonemic awareness is an important metalinguistic skill which can let students more effectively acquire reading and spelling abilities (Mehta, Foorman, Branum, & Taylor, 2005). While children learn English, an important step is to train them with high phonemic awareness (Leong, Tan, Cheng, & Hau, 2005; Goswami & Bryant, 1990). Carreker (2005) stated that phonemic awareness training helps remediate the problems of poor spelling at any age. Learners, who possess high capability of phonemic awareness, have better capabilities in pronunciation-recognition, reading, and spelling (Treiman & Baron, 1983). How to promote learner's phonemic awareness during teaching English has become an essential subject in lecture hour. Also, s/he has more opportunities than others to effectively promote her/his phonemic awareness so as to shorten the learning time of reading and spelling. During teaching pronounces in classes, most teachers in Taiwan often concentrate on teaching learners speech skills. Moreover, they neglect learners' fostering of the recognition capability of phonemic voice. This leads to the fact that the learners cannot have high pronunciation recognition ability. Therefore, the learners are unable to clearly compare their pronunciation differences with correct ones. It raises the problem of inaccurate pronunciation, late speech development, and low letter knowledge (Mann & Foy, 2007).

While learning English in classrooms, teachers often teach students English pronunciation without computer aids. In recent years, due to the growing advancement of information technologies, large amount of multimedia English learning materials have been developed to enhance the learning performance of English pronunciation (Hincks, 2003). The technology of speech analysis has been used for teaching intonational patterns since 1970s (Zinovjeva, 2005). Therefore, speech analysis has been incorporated in much commercial software for English pronunciation. However, the software is still insufficient in offering the feedback to learners for the analysis results of incorrect pronunciations. Thus, the computer assisted language learning (CALL) systems have been successfully developed to improve those limitations such that traditional CALL systems not only perform speech recognizers but also offer the language learning activity and feedback (Wachowicz & Scott, 1999). Moreover, Precoda, Halverson, and Franco (2000) presented a result that the user interface of the CALL system is designed to give pronunciation feedbacks for the learners' pronunciation ability, and a conclusion that the design of the user interface plays an important role to attract learners' attention.

Currently, speech synthesizers and digitally manipulated stimuli have been developed in laboratory studies (Neumeyer, Franco, Digalakis, & Weintraub, 2000). Unfortunately, they are not widely utilized in the design of CALL systems. As a result, linguistic experts, including the Second Language (L2) teachers, exclude to take those software products as tools to teach English pronunciation (Zinovjeva, 2005). The reason is that those systems just provide learners with speech synthesizers. They can not offer learners with learning feedback and high quality of voice. Therefore, our research devises a multimedia English Learning (MEL) system to overcome above two limits, not providing learning feedback and using speech synthesizers.

The Hidden Markov Model (HMM)-based automatic speech recognition (ASR) system has been successfully applied to dictate speech tasks (Nock & Ostendorf, 2003). HMM provides a framework which is broadly used for modeling speech patterns. The hidden Markov model (HMM) is the most commonly employed model for speech recognition. Speech recognition technology based on the HMM using for word spotting and speech recognition, has improved significantly during the past few decades (Liu et al., 2006). Although the HMMs play an important role in most recognition systems for a long time, many alternative models have been proposed in recent years to overcome shortcomings of the HMMs. High recognition rate needs higher pronunciation training cost. A disadvantage of the ASR systems is that they are highly sensitive to variations between training and testing conditions such as changes in speaker voice or acoustic environment. Moreover, a method with hierarchical clustering was proposed (Mathan & Miclet, 1990). However, this method had no depth determination procedure for a word-based speech recognition system (Kosaka, Matsunaga, & Sagayama, 1996). Therefore, the paper proposes an adaptive clustering technique to improve discrepancies mentioned above.

English is regarded as a second language in Taiwan. The learners cannot immediately have learning feedback from teachers and cannot quickly evaluate their learning level. Therefore, English learning performance of learners is not so good. This inspires us to develop a speech learning system to offer the correct feedback to learners and not to sound artificially. Therefore, this paper proposes the MEL system based on HMMs and mastery theory for the learning of English pronunciation. This system adopts a phoneme-based HMMs to perform speech recognition. The system offers feedbacks by integrating a dialogue speech tool for native English pronunciation, phonemic clustering for reducing the computational complexity, and mastery learning theory offers correct feedbacks (Marsha & Marion, 2007). Speech recognition then makes learning evaluation with the four dimensions of pronunciation, intonation, tempo, and volume (Liu et al., 2006). By the aids of this system, the learners can be able to identify their problems for speaking English and make a lot of progress due to the help of different error analyses.

The rest of this paper is organized as follows. Section 2 briefly reviews an ASR system based on HMMs and mastery learning. Section 3 describes the MEL system. Section 4 shows the experiment results, and Section 5 draws conclusions.

Background

The pronunciation difference of EFL learners

Many researches indicate that native language pronunciation significantly affects learning effects for English pronunciation (Jenkins, 2000). EFL learners easily make reading mistakes while they sound English words. The reason is that some sounds of English words are excluded in the set of sounds of native language. Some EFL learners often fuse the intonation and rhythm of the mother tongue into the pronunciation of English language. This causes incorrect pronunciation. Several papers have proposed the results that the mother tongue interferes with pronunciation correctness while speaking foreign language. The pronunciation differences between native language speakers and EFL learners can be summarized as follows (Jenkins, 2000; Wang, 2003).

- Lack: Sounds of some English words do not exist. Therefore, learners are unable to correctly pronounce the words. For example: /æ/ is pronounced as /ɛ/ because there is no extremely low-tongue location of pronunciation symbol for native language.
- Substitution: Learners substituted English pronunciation by similar native language. For example: Learners in Taiwan replace /ʃ/ with /tʃ/. This may cause incorrect pronunciation for syllable, intonation, and rhyme.
- Simplification or complexity: Learners often add or omit one consonant due to side effect of speaking mother tongue. For example: “question” is pronounced as /kwɛstʃn/.

- Epenthesis: There is no CVC (a Consonant, following Vowel, and then a Consonant) in China's ordinary speech structure. Therefore, some learners may insert one vowel to the last letter of words. Thus, CVC becomes CVCV. For example: “some” /sʌm/ takes place as /sʌmʊ/.

Mastery learning

The mastery learning is an effective way to make learners reach higher learning level. It aims at that all students can almost reach high levels of competence on instructional material. Bloom (1968) deemed that well organized teaching materials and effectively managing student's learning process are two effective instruction factors. As conceptualized by Bloom (1976) and others (Block & Burns, 1976; Fuchs, Fuchs, & Tindal, 1986), mastery learning can be accomplished by following procedures. The first step towards the realization of applying mastery learning theory is to divide the concepts and materials into relatively small and sequential learning units. Each unit should be associated with concrete learning objectives. The learning structure is organized by the way from easy units to difficult units. After teaching each unit, a formative assessment is conducted to get the results where the learners have reached the learning level or not, and also to reflect feedback on their learning (Yang & Liu, 2006). The learners, who have not mastered a unit, should enter the process of remedial activities or corrections for fully mastering the unit. The learning process can be shown in Figure 1. Mastery learning is suitable for students due to that they have a weakness in self learning. Therefore, the MEL system applies the mastery learning in the design of learning paths to teach English pronunciation in the rural primarily school in Taiwan.

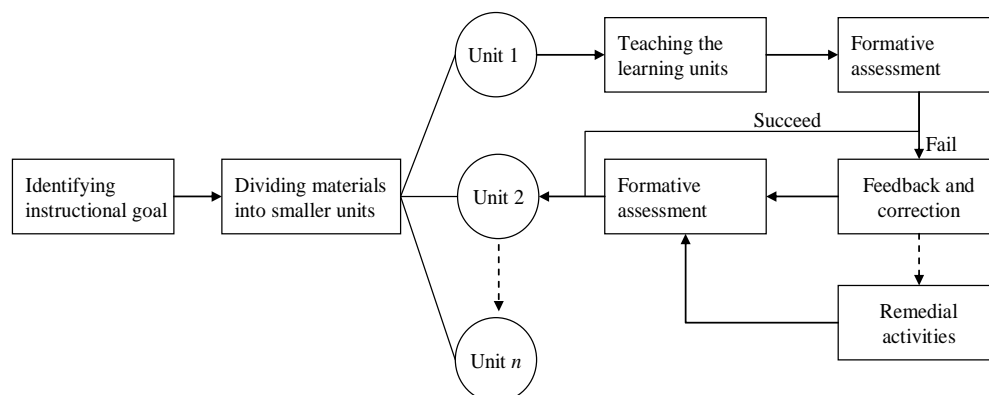


Figure 1. The strategy for mastery learning

A review of an ASR system based on HMMs

The speech signal can be expressed as a form of a sequence of samples (Young et al., 2005). Figure 2 depicts a block diagram of speech recognition using HMMs, which consists of four components, Frame Blocking (FB), Feature Extraction (FE), Parameter Construction (PC), and HMMs. Finally, the recognizer outputs the phoneme of maximum probability to be the recognition result.

Frame blocking

While analyzing speech signal, the frame procedure of blocking is involved first. Frame blocking is to partition a sequence of speech samples into a set of frames. The feature parameters associated with each frame can then be extracted. Figure 3 illustrates an example for frame blocking.

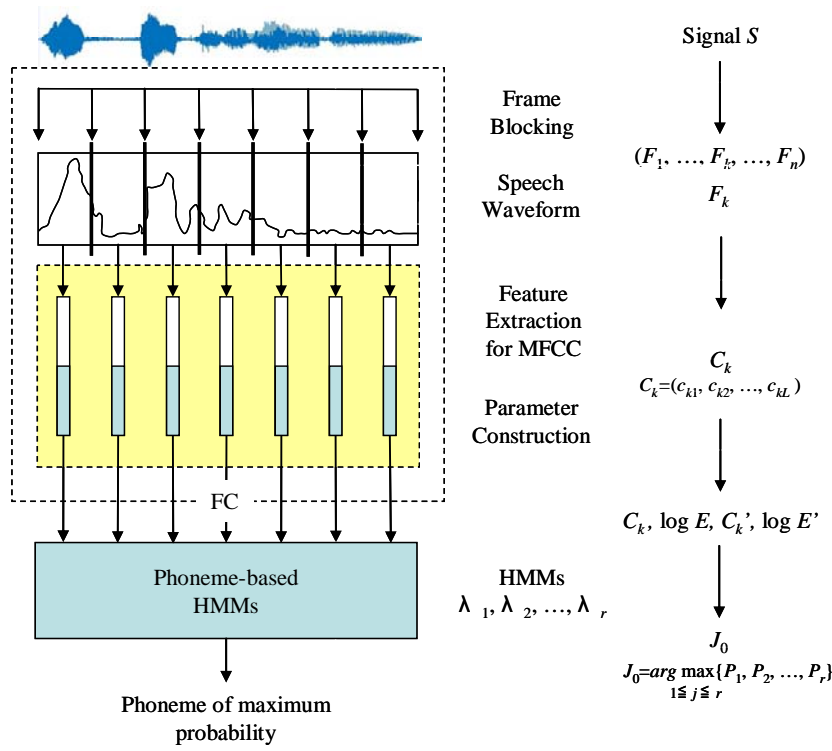


Figure 2. Block diagram of speech recognition using HMMs

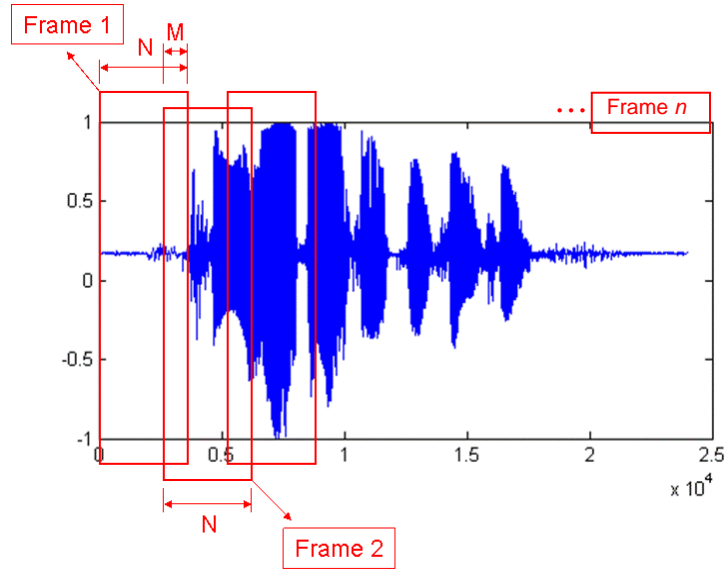


Figure 3. Speech signal with frame blocking

Let a speech signal S be partitioned into a sequence of n overlapped frames, F_1, F_2, \dots , and F_n , and be represented as

$$S = (F_1, F_2, \dots, F_n). \quad (1)$$

Assume that the frame duration and the frame overlap for S are N and M , respectively. The first frame F_1 consists of N samples, which can be denoted as

$$F_1 = (x_1, x_2, \dots, x_N), \quad (2)$$

where x_1 is the first sample and x_N is the N th sample in F_1 . Consequently, the n th frame is specified by

$$F_n = (x_{(n-1)(N-M)+1}, x_{(n-1)(N-M)+2}, \dots, x_{(n-1)(N-M)+N}). \quad (3)$$

Therefore, the equation (1) can be rewritten as

$$S = (x_1, \dots, x_i, \dots, x_{(n-1)(N-M)+N}), \quad (4)$$

where x_i denotes a speech sample, $i = 1, 2, \dots, (n-1)(N-M)+N$.

In the implementation phase, the frame duration and frame overlap are set to, generally, about 20-30ms (millisecond) and the half of the frame duration, respectively.

Feature extraction

Several kinds of methods can be used to obtain speech feature parameters such as linear prediction coding (LPC), Mel-Frequency Cepstral Coefficients (MFCC), perceptual linear predictive analysis (PLP), etc. The MFCC is the most frequently used in the computation of speech feature parameters (Zheng, Zhang, & Song, 2001). Therefore, the feature parameters, which are calculated by using the MFCC (Figure 4), are especially suitable for the application of speech recognition. After feature extraction, the feature C_k of a frame can be written as

$$C_k = (c_{k_1}, \dots, c_{k_i}, \dots, c_{k_L}, \log E_k, dc_{k_1}, \dots, dc_{k_i}, \dots, dc_{k_L}, d(\log E_k), \quad (5)$$

where E_k represents the energy expression, dc_{k_i} and $d(\log E_k)$ stand for the delta coefficients of c_{k_i} and $\log E_k$, respectively, for $i = 1, 2, \dots$, and L . Detail descriptions for MFCC can be found in (Nwe & Li, 2007; Young et al., 2005).

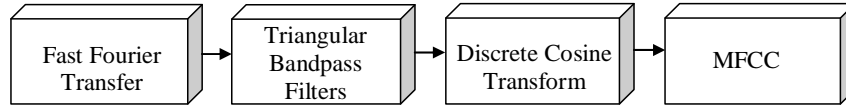


Figure 4. The procedure of feature extraction

HMM

The technique of HMMs has been efficiently applied in speech recognition (Nock & Ostendorf, 2003). Assume an HMM has a set S of M states, $S = \{S_1, S_2, \dots, S_M\}$. Each state S_i corresponds with a set of transition probability denoted by $A = \{a_{ij} \mid i, j = 1, 2, \dots, M\}$. Note that a_{ij} denotes the probability of a transformation from state S_i to state S_j . In addition, each state S_i has an observation probability distribution, $B = \{b_i(o_t)\}$, $t = 1, 2, \dots, T$. Specifically, an observation probabilities is that o_t is observed at state S_j . Accordingly, an HMM can be specified by $\lambda = (A, B, \Pi)$, where $\Pi = \{\pi_i \mid i = 1, 2, \dots, M\}$, and π_i denotes the initial probability of S_i . Figure 5 exhibits an example of an HMM with M states. An HMM λ_i is used to recognize the phoneme P_i . An HMM λ_i is used to recognize the phoneme P_i . In this paper, 39 HMMs are involved in the design of speech recognition of the MEL system.

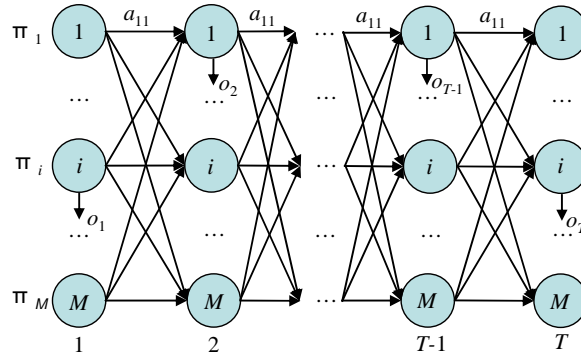


Figure 5. A diagram of HMM with M states

The MEL system

Figure 6 depicts the architecture of the MEL system which consists of three modules, the Speech Analysis Module, the Mastery Learning Module for students, and the Management Module for teachers.

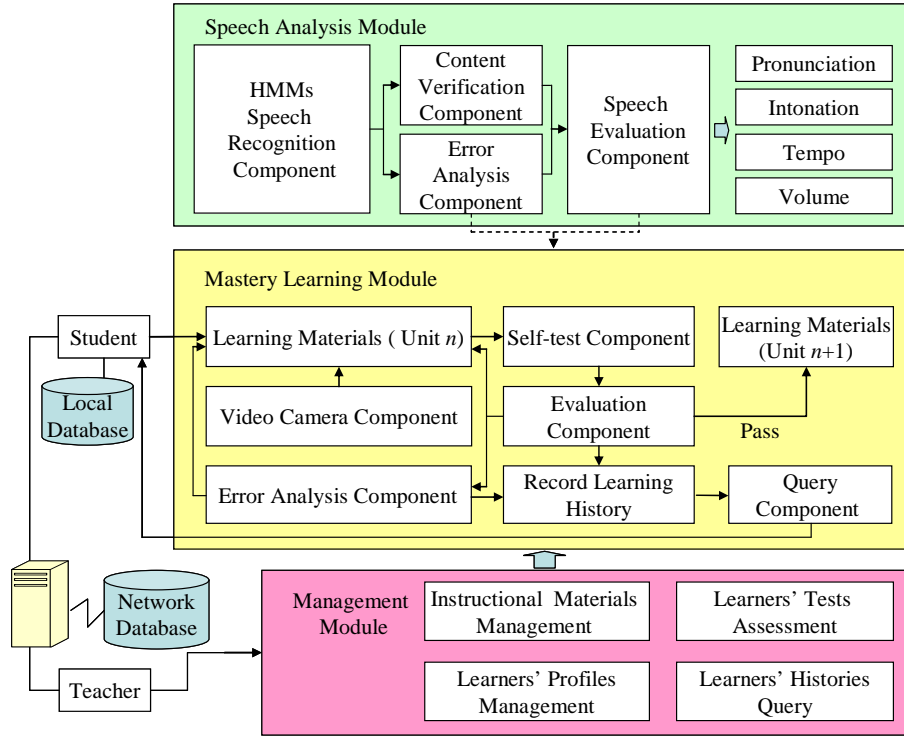


Figure 6. The architecture of the MEL

Speech recognition algorithm of the MEL system

The paper proposes an adaptive phoneme clustering (APC) algorithm. The algorithm is then used in the design of Speech Analysis Module. The goal of the algorithm is to simultaneously reduce the phoneme recognition time complexity and the recognition error rate. The Kenyon & Knott (KK) phonetic symbols are employed in this paper while constructing a phoneme recognition model for each phoneme. Thirty nine phoneme recognition models, which are constructed by HMMs, are shown in Figure 7(a). In order to speed up the recognition process, these phonemes can be classified into clusters to form a hierarchical recognition model with two levels. An example for 5 clusters of the phonemes is exhibited in Figure 7(b).

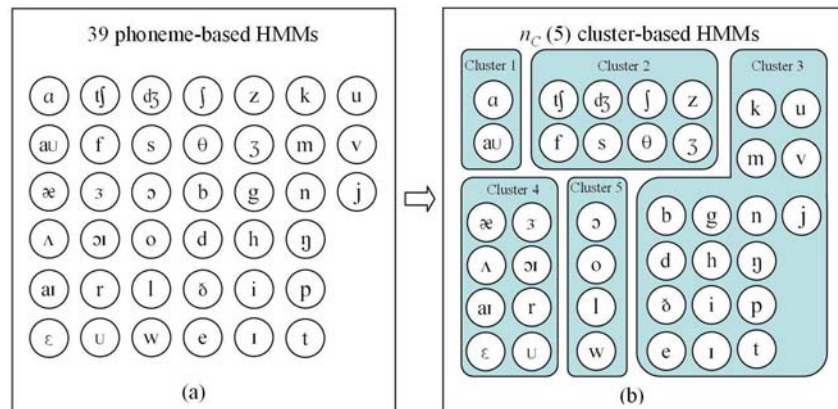


Figure 7. An example of clustering phoneme-based HMMs

During phoneme recognition, the APC algorithm first specifies which cluster the input phoneme belongs to, and then the input phoneme is recognized by involving all HMMs in the specified cluster. This way can reduce the recognition time in contrast to the method recognizing an input phoneme by using all HMMs (39 HMMs). Accordingly, the APC algorithm can reduce the recognition time.

Figure 8 displays a block diagram for the APC algorithm. Assume that there are n_{tr} training patterns, n_{te} testing patterns, and n_c clusters. First, let $\{S_1, S_2, \dots, S_{n_{tr}}\}$ denote a set of n_{tr} training patterns. After feeding the FE component with S_j , the j th sound signal, each frame F_k^j has a set C_k^j of feature parameters, where

$$C_k^j = (c_{k_1}^j, c_{k_2}^j, \dots, c_{k_n}^j). \quad (6)$$

Therefore, the training-pattern set can be expressed as a form

$$\zeta = \{C_k^j | j = 1, 2, \dots, n_{tr}, k = 1, 2, \dots, n\}. \quad (7)$$

After feeding the K-means algorithm with the set ζ , a new training-pattern set ζ' can be obtained and represented by,

$$\zeta' = \{(C_k^j, \text{cluster}_i) | i = 1, 2, \dots, n_c, j = 1, 2, \dots, n_{tr}, k = 1, 2, \dots, n\}, \quad (8)$$

where $C_k^j \in \text{cluster}_i$. In other words, ζ' is employed to construct a classification model which is realized by HMMs.

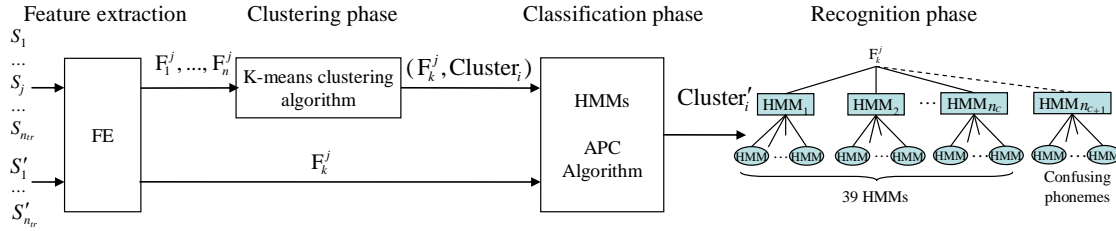


Figure 8. A block diagram for the APC algorithm

Since the Euclidean distance between two feature vectors C_k^j does not effectively measure the similarity between a phoneme and others, the HMMs are applied to model the phoneme recognition instead of applying the K-means algorithm to perform phoneme recognition. Table 1 presents an example of using the APC algorithm for the case of two clusters. The l-phoneme in the bottom row in Table 1 should be in Cluster 1 but it is labeled with Cluster 2 by using K-means algorithm. Note that in this paper the training data is the TIMIT speech database (Garofolo & Lamel, 1993).

Confusing phoneme

Some phonemes cannot be recognized correctly because these phonemes apparently exist in more than one cluster. In order to avoid incorrect cluster recognition leading to lower accuracy rate of phoneme recognition, the APC algorithm specifies a set of confusing phonemes, and then reconstructs the 2-level HMMs model with (n_c+1) clusters.

More specifically, ζ' is extended to ζ'' by replacing $(C_k^j, \text{cluster}_i)$ with $(C_k^j, \text{cluster}_{n_c+1})$ if C_k^j is a feature of a confusing phoneme. Then, a 2-level HMMs with (n_c+1) clusters can be obtained by feeding the n_c -HMMs algorithm with ζ'' . A phoneme is considered as a confusing phoneme if its error rate, $\pi_{(2)} / \sum_{i=1}^{n_c} \pi(P, i)$, exceeds a threshold,

where $\pi_i = \pi(P, i)$ denotes the number of phoneme P in the Cluster_i , and $\pi_{(1)} \geq \pi_{(2)} \geq \dots \geq \pi_{(n_c)}$. Note that the set of clusters is produced by using K-means algorithm. An example given in Table 2, there are two confusing phonemes, W and h if the threshold is set to 0.1. Table 3 shows the recognition accuracy of the MEL system in comparison with other existing methods such as Dynamic HMM (Salmela, 2001), Factorial-HMM (Virtanen, 2006), and PT-FHMM (Nock & Ostendorf, 2003).

Table 1. An example of phoneme clustering adaptive method with two clusters

| Test Data (Code) | Test Data (KK) | K-means algorithm | HMMs | Experimental Results | |
|---------------------|-------------------|----------------------|------|----------------------|-----------|
| | | | | Cluster 1 | Cluster 2 |
| AA | ɑ | 1 | 1 | 107 | 1 |
| EH | ɛ | 1 | 1 | 145 | 1 |
| ER | ɜ | 1 | 1 | 189 | 3 |
| IH | ɪ | 1 | 1 | 352 | 12 |
| HH | h | 2 | 2 | 21 | 55 |
| W | w | 2 | 2 | 24 | 70 |
| L | l | 2 | 1 | 134 | 39 |

Table 2. An example of confusing phoneme with two clusters

| Test Data (Code) | Test Data (KK) | K-means Cluster | Experimental Results | | |
|---------------------|-------------------|-----------------|----------------------|-----------|------------|
| | | | Cluster 1 | Cluster 2 | Error Rate |
| AA | ɑ | 1 | 107 | 1 | 0.009 |
| AE | æ | 1 | 158 | 1 | 0.006 |
| AH | ʌ | 1 | 171 | 4 | 0.023 |
| AY | aɪ | 1 | 100 | 0 | 0 |
| ER | ɜ | 1 | 189 | 3 | 0.016 |
| W | w | 2 | 24 | 70 | 0.255 |
| HH | h | 2 | 21 | 55 | 0.276 |

Table 3. The recognition accuracy of the MEL system in comparison with other existing methods

| Type | Dynamic HMM | Factorial-HMM | PT-FHMM | MEL |
|----------|-------------|---------------|---------|-------|
| Accuracy | 96.8% | 97.0% | 97.4% | 97.5% |

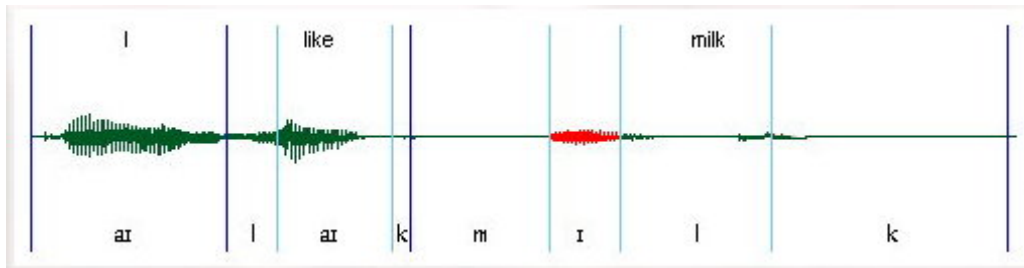


Figure 9.(a) The pronunciation error

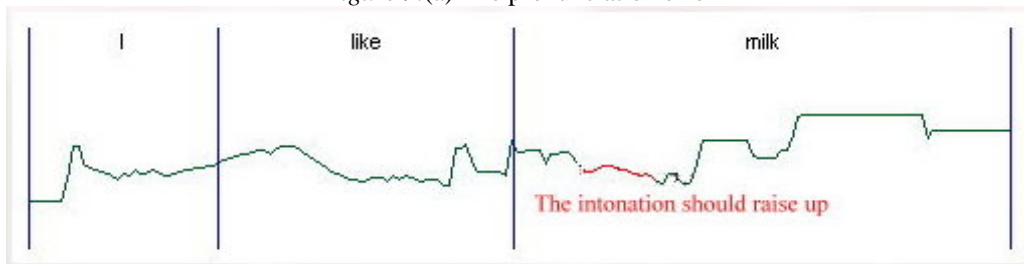


Figure 9.(b) The intonation error



Figure 9.(c) The tempo error

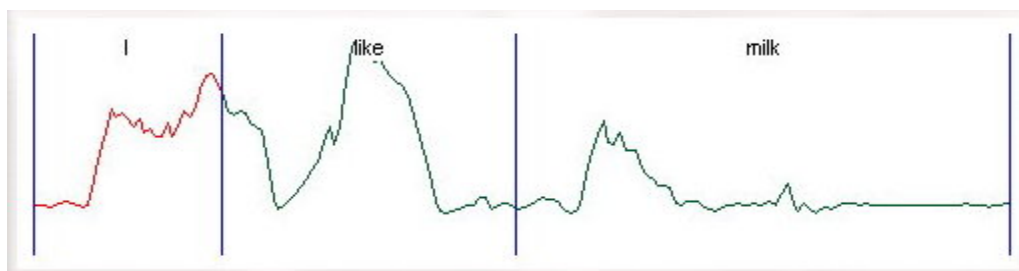


Figure 9.(d) The volume error

The models of the MEL system

Speech analysis module

In the MEL system displayed in Figure 6, the Speech Analysis Module is used to analyze the speech signal and to detect the correction of student's pronunciation. The HMMs Speech Recognition Component is employed to recognize the input speech signal and also computes the probability and ranking of phonemes. The Content Verification Component is used to prevent random utterances and the Error Analysis Component is used to compare student's pronunciation with the standard version. The Speech Evaluation Component then evaluates the correctness of the input speech signal in terms of the four factors: pronunciation, intonation, tempo, and volume.

For the pronunciation, when a student reads a sentence, the system can clearly show his/her incorrect pronunciation for the word, phrase, or sentences. It marks the interval of the voice signal to analyze the pronunciation error if the pronounce score is less than 60. Figure 9(a) shows an interval of the pronunciation error colored in Red. For the intonation, the MEL system provides the intonation curves of the teacher with students. It can display incorrect intonation to help students to correct their intonations. Figure 9(b) exhibits an interval of the intonation error colored in Red. For the analysis of tempo, the MEL system can compare the voice speed at which every student reads every word, phrase, and sentences with teachers. Figure 9(c) displays an interval of the tempo error. For the analysis of volume, the MEL system compares the volume of students with teacher's voice for their volume stress. Figure 9(d) shows an interval of the signal at aloud volume.

Mastery learning module for students

The students' learning module includes the Learning Materials Component, Self-test Component, Error Analysis Component, Video Camera Component, Record Learning History, and Query Component. The module supports small-scale teaching, sufficient opportunities to practice, plenty time to learn, and feedback for the learning. Students can practice in the units of Learning Materials Component. Each unit is divided into words, idioms and phrases, and sentences. Students can decide the learning sequence for unit's content.

The Self-test Component is used to test the student when s/he complete study from current unit. Evaluation Component is employed to support the standard pronunciation to student and decides the standard score for which student can pass the unit. Students can pass the unit if they get a score of 85. Once they pass the test, they can continue to the next unit.

According to the results of the speech analysis module, the Error Analysis Component is used to offer students with the error analysis for the pronunciation, intonation, tempo, and volume. After practicing or testing, students can get a feedback from the view to watch their sound waves and teacher's sound waves on the screen. There are three switch buttons for intonation, tempo, and volume. Students can get the performing waves and look out for errors in each of the four factors. Students can compare their results with teachers (standard sentences) to obtain the errors in terms of these four factors. Figures 9-10 show an example for student's sound wave of the sentence "I like milk". Students can see the individual score and errors for each question and, therefore, they can know the exact problems such as the pronunciation error, the intonation error, the tempo error, and the volume error while they practice their speech. Students can obtain the adequate feedback on their spoken English and naturally improve it. Video Camera

Component with charge-coupled device (CCD) function can be used to record students' lips. By replaying video, the student can review the mouth shape s/he makes while speaking.

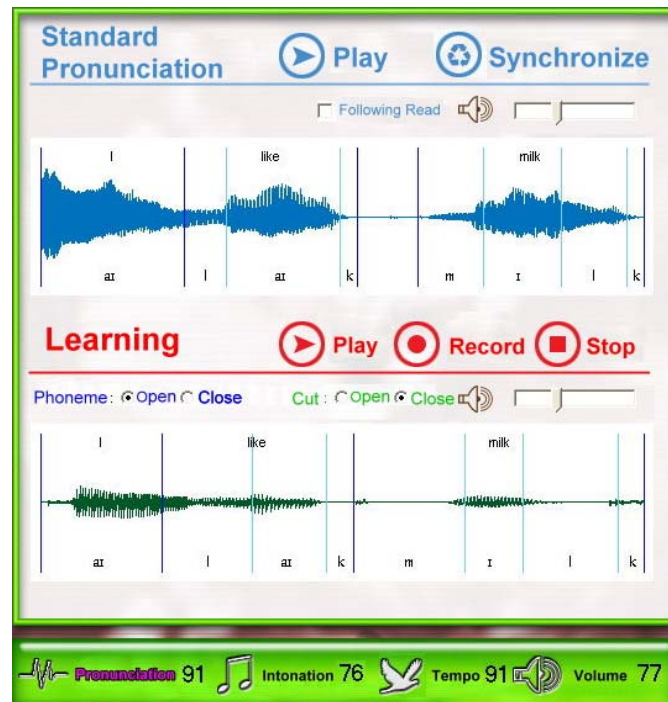


Figure 10. Student's sound wave of the sentence "I like milk"

The system can show the corresponding relation of shape-phoneme to enhance the ability of pronunciation. Figure 10 shows the corresponding of letters and phonetic symbols for student's phonemic awareness. The instruction strategy mainly relies on spelling and combining the syllables in letters, emphasizes goal analysis, word of phoneme. Students may strengthen their phonemic awareness by dividing each phoneme into a segment for each speech sound in a word. For example, while students are pronouncing the word "milk", they pronounce "milk" as the /milk/ sound. In practice, students first pronounce the letter "m" as /m/ sound, the letter "i" as /I/ sound, the letter "l" as /l/ sound, and finally the letter "k" as /k/ sound. Subsequently, the students can regard letter "m" as prefixes to practice the associating words whose the first letter is "m", such as "mill". This way can increase the practice for the pronunciation to letter "m". The students replace the second letter "i" with letter "e", such as "melk". This way can increase the practice for the pronunciation to the second letter "i" and "e".

The component, Record Learning History, is designed to record full learning experience of each student progress and test for each unit. Students can use Record Learning History to obtain their learning level. Query Component is designed to query the learning history of each unit which a student has completed the test. Students can use Query Component to get their individual score for each question and to understand the problems they have with their speech. Therefore, students can obtain adequate feedback on their spoken English and naturally improve their pronunciation skills through the MEL system which offers the students with learning feedback to modify their learning paths.

Management module for teachers

The teacher's management module can be used to manage instructional materials, manage students' profiles, assess students' tests, and query students' learning histories. The functions of management module are as follows.

The Instructional Materials Management contains the Add Unit and the Edit Unit. Teachers utilize the Add Unit while creating a new unit. Teachers can add or edit words, idioms and phrases, and sentences as new materials by using the Edit Unit. The Edit Unit also offers users a record function to record teachers' or experts' own voice which

can be regarded as teaching and learning resources. Figure 11 shows the Instructional Materials Management for editing the learning unit.

Teachers employ the Learners' Profiles Management to add and edit students' profiles. Teacher can add and manage students' accounts. The Learners' Tests Assessment is used to offer teachers to edit the questions or to set the numbers and types of questions which the test of each unit will appear. The Learners' Histories Query is used to provide teachers with a function to query students' learning histories, such as the test scores of each student and detailed score distributions. Therefore, teachers can obtain students' learning status and then provide them with appropriate assistances or guidances.

The screenshot shows the 'Instructional Materials Management' software interface. It has a title bar with the text 'Instructional Materials Management' and standard window controls. Below the title bar are two tabs: 'Add Unit' and 'Edit Unit'. The 'Edit Unit' tab is selected. Under the 'Edit Unit' tab, there is a dropdown menu for 'Unit Course' showing 'C03: 營養的早餐-A Big Breakfast'. The main area is divided into three sections: 'Word' (yellow header), 'Idiom and Phrase' (red header), and 'Sentence' (green header). Each section has input fields for the word/phrase/sentence, its Chinese translation, and a voice file path. There are also buttons for 'Record', 'Stop', 'Play', and 'Add'. A list of items is shown on the right side of each section.

Figure 11. The Instructional Materials Management for editing the learning unit

Experiment and results

Participants

In Taiwan, English is the second language. Students at the third grade begin to learn English listening and speaking in elementary school. A total of 120 third-grade students (67 females and 53 males) from an elementary school in Yunlin County participated in the study. They were recruited and randomly assigned as the experimental group and the control group, respectively. Students were ranged in age from 9 to 10 years (*Mean* = 9.6). Based on the mastery theory, the main purpose of this study was to make most of students mastery the learning contents. Therefore, this study used the phonemic awareness scores to classify students into three categories: (a) high-score group including the top 27% of the samples (experimental group $n = 16$; conventional group, $n = 16$), (b) middle-score group including the middle 46% (experimental group, $n = 28$; conventional group, $n = 28$), and (c) low-score group including the bottom 27% (experimental group, $n = 16$; conventional group, $n = 16$).

Assessment materials

Phonemic awareness test (PAT)

Phonological awareness, a total of 50 items, was measured by using the three subtests to assess phonemic recognition, deletion, and segmentation. First, the process of phonemic recognition subtest was that student pointed out which word in a list of words while s/he heard the sound of the target word. E.g., teacher pronounces the "joak"

in the list “joap, joak”, and then student should point out “joak” as the correct response. The participants were asked to recognize 16 lists with two printed words or pseudowords in each list. Subsequently, the phonemic deletion subtest was that the student deletes the initial, medial, or final phoneme of a new word or pseudoword. Student was instructed to pronounce an original word and then asked to pronounce the deleted word after removing a specific phoneme of the word. E.g., the original word was “boat”. Teacher deleted the initial “b” and then the student was asked to pronounce the deleted word “oat” without teacher’s instruction. The phonemic deletion subtest score was measured with 18 items from the task with 6 initial, 6 middle, and 6 final deletions (Leong, Tan, Cheng, & Hau, 2005). Finally, the phonemic segmentation subtest was modified by the vowel phoneme-grapheme correspondence (Landerl & Wimmer, 2000). Student listened the word-item pair and replaced the first grapheme, e.g., the words “boat-c” and “chair-t” were replaced with “coat” and “tair”, respectively. There were 16 words used in the subtest. The internal reliability of Cronbach’s coefficient α for this test was .86.

Learning achievement test (LAT)

Learning achievement test consisted of two tasks of spelling (30 points) and reading (30 points). In the first task, the spelling subtest consisted of 30 words where each word was selected from a sentence. In addition, those 30 words were sequenced in order of difficulty. E.g., teacher read the sentence “I have a lunch *break*” then asked student to spell the assigned word “*break*” with “b” “r” “e” “a” “k” (Kaufman & Kaufman, 1985). In this sample, the internal reliability of Cronbach’s coefficient α was .86. In the second task, every student read the reading Subtest I which includes 20 words in an increasing difficult order. After a student sounds the 20 words, the teacher will score the subtest for the student (Sullivan & Hawkins, 1995). The internal reliability of Cronbach’s coefficient α was .89. The reading Subtest II which includes 5 questions was used to evaluate how well students comprehend what they had read in learning units. For example, one question “Do you like salad?” four choices were given in the following (a) She is old, (b) She like it, (c) Not very much, or (d) Thank you!

Procedure

This experiment lasted 12 weeks to teach the third graders. Students were taught in their normally scheduled English language classes with two 40-min class periods a week. During the preparatory activities, researchers and teachers agreed to select six units ‘Early in the morning’, ‘I like noodles’, ..., and ‘The end of the day’ from the text book. Each unit in the teaching activities includes warm up, review, vocabulary, pattern, chant, dialogue, and assignment. For the activity of vocabulary and pattern, teachers use the MEL system to teach students to learn words, idioms, phrases, and sentences. Meanwhile, teachers also teach students how to use the MEL system after class. The system can show the corresponding relation of shape-phoneme to enhance the ability of pronunciation. Figure 9 shows the corresponding of letters and phonetic symbols for student’s phonemic awareness. The instruction strategy mainly relies on spelling and combining the syllables in letters, emphasizes goal analysis, word of phoneme. Students may strengthen their phonemic awareness by dividing each phoneme into a segment for each speech sound in a word. The practice is as follows.

1. Teachers record their or the native speaker pronunciations.
2. Students utilize the “play key” in the MEL system to listen to pronunciations recorded in the database of the MEL system.
3. Students loudly pronounce vocabularies, idioms, phrases, and sentences, and then the system records students’ pronunciations.
4. The system compares students’ pronunciation with that of the teachers for the four factors, the pronunciation, the sound intonation, the tempo, and the volume.
5. The system provides students with the learning results as shown in Figures 9-10.
6. According to the results, students obtain whether their pronunciations are well or poor.
7. Students repeat the practices to correct their errors if students deem their pronunciations have to be improved.
8. Students also practice similar words or similar sounds to make students easily obtain comparison results for the sound characteristics and differences among these similar words or similar sounds.
9. Teachers can understand the student’s learning performance by analyzing the learning profile of each student.

Before teaching, all students took Phonemic Awareness Test to compare the posttest with pretest after teaching. In the instructional activities, the teacher explained to students how to use the MEL system to proceed with their

learning. Also, the teacher used the MEL system only to assist and instruct the experimental group, so as to supply students with vocabulary listen, vocabulary presentation, pattern presentation, rhyme presentation, and test assignment. After teaching, students in the experimental group also were able to study with the MEL system and students in the control group only studied with the traditional method after the class. After 12 weeks, all students took Phonemic Awareness Test and English Achievement Test.

Data analysis

Research data were collected through the tests of the Phonemic Awareness Test and English Achievement Test. The experimental group adopted the MEL system in English learning for phonemic awareness, while the control group received the conventional English teaching and learning. Independent-samples *t*-test was involved to compute the values of the means on the phonemic awareness scores to examine for differences in pretest and posttest between the experiment group and control group. Here, the significant level was set at $p = 0.05$. The two-way ANOVA test with 2 (instructional method: MEL and convention) \times 3 (phonemic awareness level: high, middle, and low) factorial design was applied to investigate the differences between the MEL and convention for students' learning achievement.

Results

The MEL system involves phonemic awareness instead of a word. It applies mastery theory to design learning process to effectively reach learner's achievement. It provides learners with feedback consist of four features, pronunciation, intonation, speed, and volume. Table 4 shows the characteristics of the MEL system in comparison with other similar methods such as iKnowthat (iKnowthat, 2007), Phonetics Flash Animation Project (Library of English sounds, 2005), English Pronunciation (College English Web, 2006), and FluSpeak (MT Comm, 2002).

Table 5 shows the results that the differences in posttest of the experimental group with the control one, we had statistically significant differences between the two groups, $t(118) = 2.489$, $p < .05$. It was discovered that the students who studied with the MEL system obtained, on average, a better result. The mean of scores was 72.80 ($SD = 17.35$) for the experimental group, higher than the 64.55 ($SD = 18.93$) for the control one. The results showed that the experimental group was more effective than the control one.

A 2 (instructional method) \times 3 (phoneme) ANOVA revealed that MEL students' LAT scores were higher than conventional students' scores, $F(1, 114) = 11.83$, $p < .01$, $\eta^2 = .09$, and students' achievement test scores varies directly with phoneme, $F(2, 114) = 21.57$, $p < .01$, $\eta^2 = .27$ (Table 6). Scheffe's post-hoc test ($p < .05$) indicates that all three phoneme groups differed from one another. The instructional method by phoneme interaction is not significant, $F(2, 114) = 0.686$, $p > .05$, $\eta^2 = .012$. Independent *t* test reveals that the MEL students at low and middle phoneme level scored higher on the LAT than conventional students: low-phoneme group, $t(30) = 2.56$, $p < .05$; middle-phoneme group, $t(54) = 2.80$, $p < .05$; but not higher at high- phoneme group, $t(30) = 0.97$, $p > .05$. The MEL students scored higher, 3.62 (6.03%), in the low-phoneme group and, 3.53 (5.88%), in the middle-phoneme group on the LAT compared to conventional students. In contrast, the advantage of the MEL system is only 1.44 (2.4%) for the high-phoneme group.

Table 4. The characteristics of the MEL system in comparison with other similar methods

| Items | Methods | iKnowthat | Phonetics Flash Animation Project | English Pronunciation | FluSpeak | MEL system |
|----------------------------|---------|-----------|-----------------------------------|-----------------------|----------|------------|
| Pronunciation | | Yes | Yes | Yes | Yes | Yes |
| Intonation | | No | Yes | Yes | Yes | Yes |
| Speed | | No | No | No | No | Yes |
| Volume | | No | Yes | No | Yes | Yes |
| Scoring | | Yes | No | No | Yes | Yes |
| Using HMMs | | No | No | No | Yes | Yes |
| Materials management | | No | No | No | No | Yes |
| Manage learning process | | No | No | No | No | Yes |
| Split a word into phonemes | | No | No | No | No | Yes |

Table 5. The number (*n*), means (*M*), standard deviations (*SD*), and *t* value on the pre- and post-test with the ability of phonemic awareness

| | MEL | | | Convention | | | <i>t</i> value |
|-----------|----------|----------|-----------|------------|----------|-----------|----------------|
| | <i>n</i> | <i>M</i> | <i>SD</i> | <i>n</i> | <i>M</i> | <i>SD</i> | |
| Pre-test | 60 | 51.97 | 24.34 | 60 | 49.62 | 27.19 | 0.499 |
| Post-test | 60 | 72.80 | 13.75 | 60 | 64.55 | 18.93 | 2.489* |

* $p < .05$; ** $p < .01$; *ns* = not significant

Table 6. Learning achievement test scores as a function of instructional method and phoneme

| Phoneme | MEL | | | Convention | | | Total | | |
|---------|----------|----------|-----------|------------|----------|-----------|----------|----------|-----------|
| | <i>n</i> | <i>M</i> | <i>SD</i> | <i>n</i> | <i>M</i> | <i>SD</i> | <i>n</i> | <i>M</i> | <i>SD</i> |
| High | 16 | 45.19 | 4.23 | 16 | 43.75 | 4.19 | 32 | 44.47 | 4.20 |
| Middle | 28 | 42.21 | 4.35 | 28 | 38.68 | 5.06 | 56 | 40.45 | 5.01 |
| Low | 16 | 39.06 | 3.71 | 16 | 35.44 | 4.29 | 32 | 37.25 | 4.36 |
| Total | 60 | 42.17 | 4.67 | 60 | 39.17 | 5.52 | 120 | 40.67 | 5.31 |

* $p < .05$; ** $p < .01$; *ns* = not significant

Discussion and conclusion

Phonemic awareness is an important meta-linguistic skill which can let students more effectively acquire reading and spelling abilities. While children learn English, an important step is to train them with high phonemic awareness. The paper has presented the MEL system which analyzes audio samples from English-learning students, compares the student's samples with those samples of native speakers or teachers, and evaluates whether the pronunciation is correct or not. The phonemes of the samples are analyzed according to four factors, pronunciation, intonation, rhythm, and volume. The APC method is employed in the design of the MEL system for reducing the computation time of the hierarchical HMMs. The system utilizes HMMs to obtain phonemic features which are subsequently used in the process of English pronunciation errors. According to the pronunciation errors, the system provides students with advices in these four criteria for students to correct and improve their pronunciations and to improve learning effects.

Our findings reflect that the MEL system can promote the phonemic ability of the students with the middle and the low phonemic ability. These findings also support that mastery learning makes low-ability students to devise an effective control over learning situations and more opportunities in English learning courses. This concludes that the MEL system improve student's mastery level for learning and help them to obtain more achievement for English pronunciation learning. From the pedagogical point of view, possible impacts of this study are summarized as follows. First, teacher can employ the MEL system to quickly obtain student's pronunciation results (errors) in terms of four factors: pronunciation, intonation, rhythm, and volume. Accordingly, this way is easier to realize the elaborating instruction than traditional pronunciation in classrooms (without the MEL system). Second, when students repeatedly practice pronunciations, the MEL system can interactively provide concrete feedbacks. It is helpful for self-regulated learning (Butler & Winne, 1995; Mondy, Woods, & Rafi, 2008). Third, the MEL system can be readily incorporated into e-Learning environments to perform asynchronous learning so that students can practice pronunciation from anywhere at anytime.

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Learning with E-lectures: The Meaning of Learning Strategies

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ABSTRACT

Video-based e-lectures offer interactive learning and more vivid and personalized forms of self-regulated learning. Participants (N = 28) learned from either a video-based e-lecture with synchronized written transcript of oral presentation (multimodal) or an e-lecture without the transcript (unimodal presentation). Learners could be classified as “repeaters”, whose primary focus was on the lectured material, or as “surfers,” who spent less time on the lecture itself and instead used the optional links. Results showed that the learning outcomes were significantly influenced by learner strategy (with repeaters outperforming surfers), but not by presentation modality (with or without written text).

Keywords

E-learning, Multimedia learning, Interactive video, Redundancy principle, Learning strategies

Introduction

From various perspectives, learning with new media raises many hopes and expectations. Different solutions for learning with new media have been developed, e.g., web-based learning, videoconference systems, social software. Nowadays many educational institutions offer e-lectures to their students. An e-lecture can be defined as a media based lecture including an audio or video recording, synchronized slides, table of contents and optional complementary information (e.g., external links). An e-lecture can be presented with all relevant learning materials in one integrated learning environment. It can be distributed and viewed live or selected from an archive. However, they can look very different. Some of them include a video of the lecturer. Other e-lectures provide only audio recording. Most of all, an e-lecture consists of slides with relevant points mentioned by the lecturer. In only few e-lectures one can find a written transcript of the oral presentation. This article will present two kinds of a video-based e-lecture, one with synchronized text and one without text within the e-lecture. We will present the design of those two e-lectures considering instructional design principles and results of an experiment. The question will be answered whether learning results are affected by the different design of the e-lecture or the learning strategies used by students. Based on these results relevant aspects for learning with e-lectures are discussed.

Learning with interactive e-lectures

There are several advantages for learning with a video-based e-lecture but also some challenges. Within a video-based e-lecture verbal and nonverbal signals given by the lecturer can be transmitted.

An oral lecture presented in a lecture hall can be recorded and made available over the Internet. The learners have access to its content “on demand”, independent of time or location. E-Lectures can be used very flexibly. Students can easily access learning material and reuse it at any time (Demetriadis & Pombortsis, 2007). The lecture can be divided into sections and displayed in a table of content. Therefore user can select or repeat a specific topic of the presentation according to their individual motivation, interest or prior knowledge. Navigation buttons like play and pause offer learners interactivity. E-lectures are characterised by dynamic presentation and different presentation modes. Therefore, an e-lecture is a more vivid and personalized form of self-regulated learning than a hypertext learning environment. The disadvantage of this kind of learning is the lack of immediate teacher-student communication (Demetriadis & Pombortsis, 2007), and no interaction with other students or the teacher to clarify questions is possible. The lack of feedback and higher degree of intrinsic motivation and self-regulated learning are also relevant aspects for learning with e-lectures.

Demetriadis and Pombortsis (2007) propose that e-lectures “can be safely used as students’ introductory learning material to increase flexibility of learning, but only within a pedagogically limited perspective of learning as knowledge acquisition (as opposed to construction)” (p.156). Interactivity is the salient factor of a video-based e-lecture. The learner can adapt the representation to his or her individual needs. Interactive videos with navigation buttons give learners the opportunity to stop, pause, play and rewind the lecture. In this case, basic navigation options and natural mapping devices are required (Clark & Mayer, 2003; Norman, 1988). Common navigation options can avoid cognitive load. The learners recognize buttons like “play” and “stop” from regular media players (e.g., Windows Media, Real Player). Previous research has confirmed that these interactive possibilities are helpful for learners (Schwan & Riempp, 2004). In an experimental study from Schwan and Riempp (2004), subjects had to learn to tie nautical knots. They watched either non-interactive or interactive videos. In the condition of non-interactive video viewing, the subjects needed more time to learn. The learners in the interactive conditions made heavy use of the interactive features. The interactive behaviour increased with the difficulty of the learning material (Schwan & Riempp, 2004). Therefore, interactive possibilities for learners are necessary – especially for difficult topics. Learners can repeat relevant information for a better understanding and thus for effective knowledge acquisition.

Another study focused on the influence of an interactive video on learning outcomes and learner satisfaction (Zhang, Zhou, Briggs & Nunamaker, 2006). The authors compared four groups. One group learned with an interactive video, one with a non-interactive video, one group watched no video and one group learned in a traditional classroom setting. Learners had random content access through control buttons in the condition with the interactive video. The results confirmed previous findings; learners with the interactive video outperformed learners in the two other conditions and they also reported a higher level of satisfaction with the learning environment.

An e-lecture can offer additional links with additional information and learning materials for learners. But additional information like external links is not always helpful for learners. Niederhauser, Reynolds, Salmen, and Skolmoski (2000) found that a frequent use of links in reading hypertext has a negative influence on the learning outcome. Especially if links show no direct connection to the content of the lecture but rather are added interesting material, hyperlinks may inhibit learning. In the Study of Zhu (1999), students learned with a hypermedia system. The results showed that in a “fewer-links” condition (3-7 links), learners performed significantly better than learners in the “more-links” condition (8-14 links). Zahn, Barquero and Schwan (2004) varied the number and integration of links in a hypervideo system. Groups 1 and 2 had to learn with a hypervideo including 15 or 30 links which were sequentially integrated in the video. For another two groups, the links (15 vs. 30) were presented as a cluster at the end of the video. A control group received the learning material without links. The results showed no significant effect of the groups. Participants of the experiment learned comparably well, and no differences in knowledge acquisition could be found. The number and position of hyperlinks did not influence learners’ performance. But learners evaluated the learning material with 15 links more positively than participants whose learning material had included 30 links. Zahn et al. (2004) correlated the exploration activities and rewind-actions with the use of hyperlinks and the use of video recorder functions. The analyses showed that as interactive behaviour increases, comprehension and acquired knowledge increase as well. These studies clearly demonstrate the benefits of interactive videos.

E-lectures can be seen as a new possibility for knowledge distribution and as a complement to learning from hypertexts. But how should an e-lecture be designed? Do any design factors affect knowledge acquisition? The next sections will take a look at some relevant aspects.

Instructional design principles and learning strategies

The principles for multimedia learning are based on the theory of limited cognitive capacities (Mayer, 2001). There is evidence of two processing systems in the working memory, namely visual and auditory processing (Baddeley, 1997; Mayer & Moreno, 1998). In order to avoid cognitive load during knowledge acquisition, it is better to tap the full potential of the working memory by addressing both systems (Baddeley, 1997, Mayer, 2001, Mayer & Moreno, 2003). A combination of different presentation forms leads to better learning outcomes (Clark & Mayer, 2003; Mayer, 2001). The modality principle relies on the assumption, that it is better to use spoken text than printed text within an animation. (Clark & Mayer, 2003, Mousavi, Low & Sweller, 1995). But this principle is limited to audio recordings. What about e-lecture? Within a video, the audio channel and visual channel are equally stressed. If slides

and additional synchronously presented on-screen text are included, these also tax the visual channel. When spoken and on-screen text synchronously explain graphics, the on-screen text becomes redundant. This is known as the so called “redundancy principle” (Clark & Mayer, 2003, Mayer, 2001). Clark & Mayer (2003) recommend that on-screen text should remain only to describe complex knowledge domains. On the assumption that learning content presented in a foreign language is complex, on-screen text could be helpful for learners. In this case, Clark and Mayer (2003) recommend offering redundant on-screen text.

Another relevant aspect of effective knowledge acquisition is the use of learning strategies (Schmeck, 1988, Mayer, 1988, Weinstein & Mayer, 1986). “Learning strategies can be defined as behaviours of a learner that are intended to influence how the learner processes information” (Mayer, 1988, p. 11). Weinstein and Mayer (1986) describe these strategies as rehearsal, elaboration, organizational and monitoring strategies. Further they differentiate between basic and complex strategies. According to the active-processing assumption, humans are active processors who pay attention, select and organised information. The cognitive theory of multimedia learning (Mayer, 2001) includes these aspects. But what about active strategies to learn through e-lectures? Can different strategies be identified and do they have an impact on learning outcomes?

The principles identified by Mayer (2001) are based on learning in the fields of science and mechanics; multimedia presentations are primary linear computer animations. What about other tasks like learning a foreign language or learning with an e-lecture? Clark and Mayer (2003) argue that additional on-screen text can sometimes be indicated and not redundant, for example when “the audience has language differences” (Clark & Mayer, 2003, p.108).

In sum, this paper addresses the following research questions:

- In which way do learners use an e-lecture?
- Do different strategies have an impact on learning outcomes?
- How important are instructional design principles like additional printed text with spoken text for learning within an e-lecture?

Learning strategies are helpful for effective knowledge acquisition (Schmeck, 1988, Mayer, 1988, Weinstein & Mayer, 1986). Therefore our assumption for learning with an e-lecture is:

Hypotheses 1: Learners who use learning strategies have significant better knowledge test results than learners who do not use such learning strategies.

Learning a foreign language can be difficult. New words, grammar, pronunciation, conversation and writing must be learned. As postulated by Clark and Mayer (2003), additional written text with spoken text can help learners with knowledge acquisition. Thus the additional written text is not redundant, it is perhaps even necessary.

Hypotheses 2: Learners in a condition with additional written text within an e-lecture have better test results than learners who learn from an e-lecture with no written text.

Method

Participants

Twenty-eight participants (14 male and 14 female students from the Johannes Kepler University Linz) took part in the study. Eighteen of the students were studying business administration and economics and four are studying education. In each of the case one student studied information management, sociology, mechatronics and chemical engineering.

Their mean age was 25.3 years (Standard Deviation = 2.4). Students received a small incentive for their participation. The e-lecture was in English, but the participants spoke German. The Austrian students had to complete the course “English Text Production I.” This course was a prerequisite for participation in the study, to assure a common level of English knowledge and comprehension. The topic of the e-lecture was corporate success. To determine prior expertise, subjects were asked five questions about business administration and economic terms. In a questionnaire, they had to rate their previous knowledge about the learning topic (five-point scale: “I can apply

and work with it" = 1, "I can describe and explain it" = 2, "I understand what it is" = 3, "I have heard about it" = 4, "I have never heard about it" = 5, i.e., "competitive advantage", Mean = 2.50, Standard Deviation = .96). T-Test was used to analyze whether a difference regarding the mean could be found (Bortz, 2005). The result shows no significant differences between the experimental conditions on the five variables ($t(28) = 1.02, p > .05$).

Stimulus material and experimental setting

The e-lecture, which has been selected from the University of Warwick, was about business successes of the last century and industrial economics. The e-lecture was modified with Openworld Presenter Plus version 1.24. The modified lecture can be seen in Figure 1. It consisted of five chapters, 40 slides and 13 additional links. The duration of the lecture was roughly 25 minutes. The e-lecture consisted of a video, slides, table of contents, external links and video control buttons. The slides showed pictures of mentioned persons, display diagrams and tables, along with keywords mentioned in the speech. The slides were also synchronized with the lecturer. The transitions from one chapter to the next proceeded automatically, but a table of contents allowed participants to navigate between the chapters. Therefore they had the possibility to replay chapters. Furthermore, another section in the e-lecture provided a selection of relevant external web links, which appeared throughout the lecture and offered the viewer additional resources. Participants could use the links if they wanted.



Figure 1: The e-lecture used in the experiment

The e-lecture covered five subtopics: It started with a short introduction to the topic, followed by a case study of BMW as a successful company. Next, the definition of business success and how to measure that success, as well as the relationship between economic rents and profits, were explained. The video showed mainly the lecturer, with the exception of chapters two and three, where this setting was interrupted by a short video sequence of a BMW car and

a soccer team. The lecture could be paused and replayed with familiar video control buttons (real media player). It was also possible to navigate forward and backward with a timeline. Thus, the e-lecture was designed as an interactive video.

For the experimental setting, two kinds of lecture were designed. One e-lecture had a text transcript in addition to the spoken text. The text contained the same information, which the lecturer presented and was synchronized with the video. The other e-lecture had no synchronized text, so the space for the text was empty. The experiment was run as one factorial design with a unimodal presentation (spoken text) and a multimodal presentation (spoken & written text). The multimodal e-lecture included a synchronized written transcript of the oral presentation, whereas the text in the same window was missing for the unimodal presentation. The participants were randomly assigned to these two presentations. The experiment was run in individual sessions at the Johannes Kepler University. After a short welcome, the procedure of the experiment and the software functions were explained to the students. The participants were asked to imagine that they attended a management course where they had missed one meeting due to illness or other reasons and were now preparing themselves for an upcoming exam, which they knew might take place during the next class. Their task was to memorize the presented information and operate within the e-lecture as if they were studying for an upcoming exam. Although the duration of the e-lecture was roughly 25 minutes, the subjects had 40 minutes time to deal with the learning content. They could abandon the learning process as soon as they felt that they had acquired sufficient knowledge to pass the exam. During their learning phase, the participants were allowed to replay the e-lecture. They were not permitted to take notes.

After the learning phase, the participants were asked to take a ten minute test. The test consisted of ten multiple choice questions. The results of the test were used as the dependent variable. Afterwards, participants were asked to complete a questionnaire where they evaluated the e-lecture they had just worked with and reported what their focus had been.

Data analysis

Content analysis was used to identify the learning strategies. The actions of the participants were recorded with a screen recording program (Camtasia recorder <http://www.techsmith.com/camtasia.asp>). All mouse movements, navigation action and the use of links and table of contents were recorded. Based on these log-files, a detailed transcription of the learners' behavior was made. The following categories were used to analyze the transcript and thus to identify the learning strategies: segments of uninterrupted viewing, repetitions, interruption, use of table of contents and use of external links. The segments of uninterrupted viewing included the use of the buttons play, pause and stop and forward or backward. Repetitions were defined as the replay of chapters or sections. Also the use of table of contents and use of external links were analyzed in detail. Viewing a link for less than 20 seconds was disregarded, since it was impossible to read through the text in that time period. Sometimes the browser window took some time to open, so the action consisted merely of opening and closing the browser window. The transcripts were analyzed by two independent raters (Cohen's κ : .94). Cohen's Kappa coefficient was used to measure the inter-rater agreement. The value of .94 shows a very good agreement. The recorded data allowed a detailed description of how participants worked and studied using the e-lecture. It was possible to determine how often subjects paused, replayed or stopped the course and also how interactive elements like links were used.

After coding the transcript, the data were analysed by the following criteria: how often and which repetition strategies were used, how often and how long links were used and the interruption of the lecture through external links were analysed. With this method, two different learning strategies were identified, namely "repeater" and "surfer". Repeaters were characterized by a primary focus on the given lecture material. They studied the lecture extensively through repeated cycles. Only three or fewer links were used for more than 20 seconds. Participants first watched the lecture with no or only short interruptions and then repeated some sections or chapters when they had finished their first run of the e-lecture. Other subjects reviewed part of the lecture right from the beginning of the learning phase. The second type of learner, namely the "surfers," used bookmarks and links for accessing additional external information. Some participants paused the e-lecture to spend time focusing on the additional links. Others were distracted by the links and viewed the links without interrupting the e-lecture. Overall the focus was not primary on the e-lecture.

In general, 10 repeaters and 14 surfers were identified (Tab.1). The remaining four learners were excluded from further analysis because of their low level of learning activities and the low cell allocation. Only one of these four learned with the unimodal presentation style.

Table 1. Number of Participants

| | Repeaters | Surfers |
|-------------------------|-----------|---------|
| Multimodal presentation | 5 | 6 |
| Unimodal presentation | 5 | 8 |

Results

A 2x2 (form of content x learner strategy) analysis of variance (ANOVA) was conducted (Bortz, 2005). These analyses revealed that the learning outcomes were significantly influenced by learner strategy ($F(1,24) = 5.16, p < .05$), but not by presentation modality ($F(1,24) = .54, p > .05$). In particular, “repeaters” outperformed “surfers” with regard to the knowledge test. No interaction between the two factors was found ($F(1,24) = .54, p > .05$). Participants in the unimodal condition did perform nearly as well as learners in the multimodal condition (Tab.2). These results support the first hypothesis, but the second hypothesis must be rejected. The additional text in the multimodal presentation did not hinder learning as postulated by cognitive load nor did it facilitate learning in terms of a multimedia effect. The learning strategies of the users played a major role for learning outcomes.

Does the learning environment have any significant influence on which strategy (repeating or surfing) participants choose? To answer this question, a Chi-Square test was carried out. The test result showed that there is no significant connection between learning environment and the chosen strategy ($\chi^2 = 5.43, df = 2, p > .05$). Thus the applied strategy was not influenced by the given learning environment. The results show that the learning environment in which the learning content was presented (multimodal vs. unimodal) did not substantially influence the learning strategies of the learners.

Table 2. Means (M) and Standard deviations (SD) of learning

| | Unimodal | | Multimodal | |
|----|----------|--------|------------|--------|
| | Repeater | Surfer | Repeater | Surfer |
| M | 7.20 | 5.50 | 7.20 | 6.33 |
| SD | 0.84 | 1.60 | 1.64 | 1.03 |

Discussion

In an experimental setting, participants had to learn either with a multimodal presentation or with an unimodal presentation. The multimodal presentation included an additional synchronized written transcript of the speaker. The unimodal presentation did not include this text. The results show that the usage of the e-lecture varied from person to person. Learners made use of the interactive possibilities of video-based e-lectures. Their actions ranged from very low activity to high activity in navigation. Some focused primary on the lecture, while others used the given links. Two main types of learners were identified, namely “repeaters” and “surfers”. “Repeaters” outperformed “surfers”: they showed better test results. Therefore, learning strategy was an important determinant of learning outcomes. In contrast, mode of presentation did not have substantial impact on usage or learning outcome. These results are in line with previous findings (Zahn et al, 2004, Zhang et al, 2006). The results also show that the written transcript of the oral presentation had no effect on learning performance. It can be argued that especially for language acquisition the additional text is helpful, because the topic is not easy to learn. Being presented with learning material in a foreign language makes knowledge acquisition more difficult. Therefore, additional on-screen text may be helpful for learners. But subjects in the multimodal presentation with the on-screen text did not outperform participants who learned without the text. The on-screen text was synchronized with the slides and the lecturer. This means that the text ran at a default speed. Maybe it would be helpful for learners, that they can control the text speed. Another possibility is to make the text available as an additional document. Further research can clarify how an additional text should be presented to learners within an e-lecture presentation.

Another aspect is the usage of links. “Surfers” used more links, but links distracted learners from relevant learning content. The important information for learning was presented in the lecture itself, and this topic formed the basis of the test. It was not necessary to explore the additional links. This phenomenon could be responsible for non-effective learning outcomes like Niederhauser et al. (2000) also suggested. In further studies it will be interesting to determine how to deal with links in a learning environment. Is it necessary to differ between interesting but optional additional information and links with relevant learning material? Learners’ grasp of the information presented on other websites needs to be examined with a test as well. It is necessary to develop adequate strategies for learning with additional information. It is important that learners are not distracted from learning the relevant topics and avoid cognitive overload.

The results presented in this article are based on an experiment. Learners were confronted with a time limit for preparation. The e-lecture was presented on CD-Rom. The presentation was not web-based. But the usual way to learn with e-lectures is web-based and therefore learners need high-speed Internet. Technical problems were excluded in the experiment but may affect learning in real learning situations.

For further research it will be interesting to determine whether scaffolding students in using learning strategies has an impact on successful learning. Maybe some prompts in the e-lecture are helpful to enhance the usage of cognitive and metacognitive strategies. Another research focus can be the investigation of the relevance of self-assessment possibilities after an e-lecture presentation. E-lectures offer a lot of flexible learning possibilities, but there is little research about the design and adequate usage for effective learning.

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Classroom e-Science: Exposing the Work to Make it Work

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ABSTRACT

Engaging students in science learning can be challenging, and incorporating new forms of technology into science has been shown to provide creative learning experiences. However most technology enhanced learning and e-Science experiences to date have been designed and run by researchers. There is significant challenge in moving these experiences into the hands of teachers to become an everyday part of learning. One step forward is to understand better the work involved in making these learning experiences work. We present a retrospective analysis of two educational e-Science research projects, each involving access to and analysis of scientific data from remote and handheld sensors; collaboration; and reviewing shared data using advanced software tools. We identify key categories of work from the effort, resources and issues entailed in setting-up and running these experiences. We propose these categories can be used: to help plan other technology enhanced learning experiences, to be further tested and evolved in future research, and as a basis for an overall experience framework to capture the process- and context-related aspects in which these tasks are embedded. Ultimately, the goal is to develop tools and resources that will support categories of significant work, enabling full classroom integration of e-Science learning experiences.

Keywords

Technology integration, Cooperative/ collaborative learning, Identifying categories of work, Learning communities, Framework

Introduction

Recent advances in wireless and mobile technologies have the potential to transform learning, both in and beyond, the classroom by engaging students in innovative exploratory learning activities (Luchini et al., 2002; Price et al., 2003; Sharples et al., 2002). Experiences have been created across a wide range of subject-areas using varying configurations of mobile devices, sensors, and wireless networks, and demonstrate the transformative potential of these technologies. Examples include: finding inspiration for creative writing (Halloran et al., 2006); collaborating remotely in canal explorations (Sharples et al., 2002); exploring local habitats with sensors, personal digital assistants (PDAs) and walkie-talkies e.g. Ambient Wood (Rogers et al., 2004); interacting with remote experts (Pea et al., 1997); and using mobile games and location-based role play e.g., to explore wild animal survival strategies in Savannah (Facer et al., 2004).

Scientific enquiry has been a particular focus for many of these mobile learning experiences, where science learning experiences comprise a wide variety of activities within a session; for example, personal research, group discussion and debate, small group experiment planning, exploratory data gathering, data review and reflection, and collaborative discussion. 'Educational e-Science' has been coined to more specifically denote "the use of ICT in education, to enable local and remote communication and collaboration on scientific topics and with scientific data" (Woodgate & Stanton Fraser, 2005). Such experiences make use of, or simulate use of, the same global e-Science infrastructures that 'real scientists' use for scientific data access, data visualisation and global scientific collaboration (De Roure & Goble, submitted; Gabrielli et al., 2006; Steed, 2004). Although currently no single application or platform provides the range of functionality implied for this science work, the availability and use of mobile technologies (e.g. sensors, mobile phones, PDAs) and web 2.0 technologies (e.g. for blogging, communication) in both learning and science research indicates a promising area for real-world, technology enhanced science learning. Educational e-Science is seen as having particular potential to engage young people with meaningful science in new ways and to support the development of new forms of scientific enquiry skills (Woodgate & Stanton Fraser, 2005). This is timely in the UK, as in many other countries, as there is increasing concern about the low uptake of science by students at higher levels, negative perceptions of typical scientists' work and working environments (Scherz & Oren, 2006) and the lack of current opportunities for 'creative science' within schools that inspire and challenge future scientists (Nesta, 2005).

However, while the potential for such innovative learning experiences is widely acknowledged (Heath et al., 2005; Kravcik et al., 2004; Roschelle, 2003; Sims Parr et al., 2002), moving these activities into the classroom on a large scale is a significant jump. Most projects to date have been researcher-led and run as pilot studies rather than being systemically embedded into teaching practices. Even where teachers have been closely involved, many of the studies, our own included, are largely owned, designed and run by the researchers, not by teachers and tend to be run as innovative one-off experiences, or over a limited number of sessions. They also tend to involve a team of researchers bringing different multi-disciplinary strengths, e.g., technology, pedagogy, interaction design. The fact that we as researchers need to spend some months planning and developing tools and setting up experiences points to the gap between what is potentially invaluable as a learning experience for children and what is practically deployable in repeatable, everyday ways. For example, McFarlane et al. (2007) have described the implementation of mobile learning projects as “logistically challenging”. Teachers work in highly time pressured environments and, in the main, do not have the time, skills or resources to experiment. They need to deliver learning experiences that integrate well both with the curriculum and the pragmatics of their busy daily school life and environments with limited access to time, resources and money.

The key question then is: how do we move from innovative researcher-led learning experiences to ‘everyday’ teacher-led learning experiences in the classroom? A first step in answering this question is to develop a systematic understanding of what is currently required to deliver these researcher-led innovative learning experiences. What is the work to make them work? If we can understand the effort required, along with the skills and resources that support this effort, we can start to think about how best to support the transition into the hands of the teachers and into everyday teaching practice.

To this end, we reflect on our experiences with two related environmental e-Science projects conducted with secondary school students over a nine month period. Our focus here is not on the learning related outcomes of those projects, which are available elsewhere (Smith et al., 2005; Smith et al., 2006; Stanton Fraser et al., 2005; Underwood et al., 2004) but rather on the work we needed to do to facilitate the setting up and running of educational technology enhanced experiences in authentic university and school contexts. From a retrospective analysis of project archives, including email communications and internal documents, combined with the participant-observer accounts of the researchers involved, we have identified a set of generic categories of ‘hidden work’.

The contribution from this work is twofold: the presentation of the categories themselves starts to articulate a vocabulary for anticipating as well as reporting on hidden work. Further, these categories, and the understandings and lessons learnt about the work entailed in them, have been used to develop an experience planning framework. We suggest this framework can be used in a variety of ways: to support and guide the planning and conduct of future technology enhanced learning projects; and to support the a priori collection of data about hidden work to further validate and evolve our categories. In revealing the variety of work required to make the sessions work we can also identify the support services that might be needed to enable regular delivery of similar learning experiences in real-world contexts. While these categories have been produced from a study of educational e-Science experiences, we suggest they will have more general applicability for the design of technology enhanced learning experiences.

Related work

The notion of understanding ‘the work to make things work’ is not new (Bowers, 1994) but because it tends to represent the ‘boring’ work, e.g., around the staging of an experience or in support of the more visible work, it is often overlooked in discussions.

A number of different concepts have emerged that capture some sense of the ‘double level’ nature of action, the two levels mostly reflecting a sense of the *core work activity*, here the science learning experience, and the *work about the work*. One commonly used distinction is between *formal and informal* work activities (Perin, 1991; Rodden & Schmidt, 1994). The formal work activities concern the visible performance of the work. The informal activities are more to do with the conversations about the work, the casual ad hoc interactions and activities often rendered invisible in formal accounts of work (Star, 1991) the ‘invisible work’ (Star & Strauss, 1999) or ‘hidden work’ (Schwarz et al., 1999). *Articulation work* (Strauss, 1988) is a concept closely associated with this invisible ‘work about the work’, ensuring that individual activities help achieve some collective goal: “. . . individual yet interdependent activities must be coordinated, scheduled, aligned, meshed, integrated, etc. — in short: articulated.

That is, the orderly accomplishment of cooperative work requires what has been termed *articulation work*.” (Schmidt & Simone, 1996, p. 158).

This ‘hidden work’ is critically important for the practical achievement of experiences on the ground – it is the work to make them work. The failure to take into account ‘hidden work’ has resulted in the development of inadequate technologies (Halloran et al., 2002) that often do not match work processes and contexts, to the point where they are either not used or people have to engage in elaborate work-arounds to enable them to do their job (Bowers et al., 1995). In the world of teaching, where concerns about the time and effort required for lesson-preparation are high, ‘hidden work’ becomes all the more important to understand if we are to move the design and delivery of e-Science experiences into the hands of the teachers. Understanding the broader delivery context of this work is critical and has been identified as a factor in the success or failure of technology in education (e.g. Wood et al., 1999).

To date, the focus of reporting of exploratory learning experiences has largely been on the visible work, i.e., the interactions during the experience. This is understandable given the exploratory nature of these experiences where researchers are looking to make the case for how new technologies can enhance the learning experience and so focus on the learner interactions. It may also be the case that people are reticent to specify the actual human input that was required to make the experience a success (Facer et al., 2004; Rogers et al., 2004). Either way, there is little to be gleaned from reports on educational e-Science experiences in particular, and technology enhanced learning experiences in general, about exactly what is required to put them to work, e.g. in the more organisational areas of effort required such as identifying and bringing together suitable participants; identifying, acquiring, troubleshooting and testing equipment, etc. Where there are such accounts, they are often comparative accounts of moving technologies outdoors. Harris et al. (2004), for example, report on the issues they encountered when creating an exploratory learning experience in a woodland area using wireless technologies and compare this to running a similar experience indoors. Azuma (1999) similarly reports the technology challenges faced when moving an augmented reality system outdoors. To our knowledge there has been little focus on, nor systematic accounts of, the human effort and resources involved in new learning activities. There has been a more recent effort to understand the longitudinal effort of embedding new tangible technologies into the classroom where Parkes et al. (2008) have reported on the design and pedagogical issues in using their Topobo system in different classrooms, identifying support for educators, such as through examples, as a key factor.

Now that the case for the learning-outcome value of innovative technologies is being made, it seems timely to turn attention to the next level of exploration and to understand the effort involved in delivering this value from the perspective of the designers/educators. We go on here to re-visit two educational e-Science projects we have been involved in as researchers and attempt to provide a post-hoc account of the nature and amount of ‘hidden work’ involved in delivering these projects. Whilst not a focus on teacher effort per se, it will start to point to the types of work they will need to undertake to deliver creative science learning experiences for learners. In the following section we go on to introduce these projects and explain the methodology we used to derive the categories of ‘work to put e-Science to work’.

Methodology

Context of case study: two e-Science projects

The two projects that form the focus of this paper are called ‘SENSE’ and ‘Public Understanding for Environmental e-Science’. Over a nine-month period we ran a total of 21 e-Science learning sessions with 13-16 year old science students and their teachers. There were two different types of sessions:

- A series of one-off sessions for ‘Gifted and Talented’ (G&T) students who participated in a university setting around themes of Antarctic remote sensing and urban carbon monoxide (CO) monitoring (Public Understanding project);
- A series of inter-connected sessions across the complete scientific enquiry process around urban CO monitoring for GCSE (in the UK, GCSE is the General Certificate of Secondary Education undertaken by all 16 year old students) pupils in the school context (SENSE project).

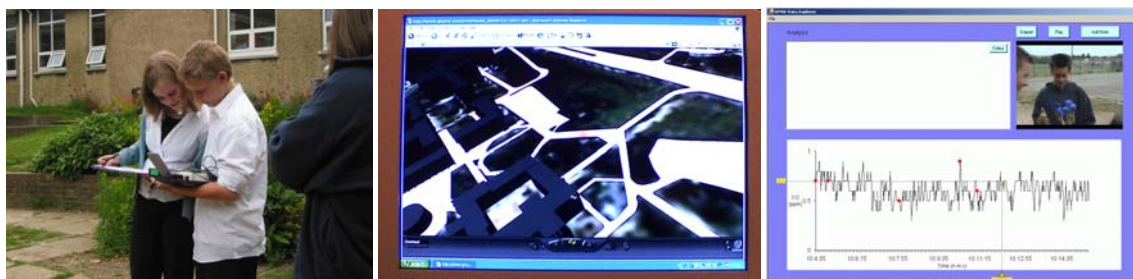


Figure 1 - Learners gather and analyse carbon monoxide data in their locality

The projects were largely researcher-led, however we engaged the teachers in the iterative design of the experiences as part of a user-centred approach. The teachers were also involved as observers, with one teacher additionally taking on a more direct role in the Public Understanding sessions. Both projects were designed to include e-Science related activities that challenged students to:

1. think about the work of real scientists in the domain of air pollution;
2. process and interpret data collected by others in remote locations;
3. engage in hands-on, practical data collection, processing, assimilation, and reflection to try out their own pollution hypotheses in their local environment;
4. communicate with real scientists in remote locations through known and readily available communication methods.

Both projects used environmental e-Science research supported by the Equator research group's e-Science theme ("Equator Research Group, e-Science Theme," 2008) to source devices, science experts and material for use in the sessions. Activities to contextualise the science domain included a webquest of challenges to create explanations for unfamiliar images relating to the air pollution topic. For the hands-on component (part 3 above) students worked in a group of four, accompanied by a facilitator, to capture data about their own outdoor environment (Figure 1). Each was given a role to play e.g., video recorder, CO and global positioning system (GPS) tracker, or route planner and note taker. In the process of collecting their data, they engaged in group decisions and accounts of their activities to reflect on readings on-the-fly. Once back in the classroom, we transferred their data from the handheld technology to a desk-top machine to combine and re-visualise the collected data sources and allow reflection on the experience as a whole. Additional activities included 'live' chats with a remote scientist (both projects) and collaboration with a remote classroom (SENSE only). For further detail see Smith et al. (2007).

Participants

Participants involved in each project were recruited on a voluntary basis from local schools in Brighton, UK. No participants were involved in both projects. A summary of their ages and session involvement is shown in Table 1.

Table 1 - Summary of participants and sessions

| Session Type | Total Number of Learners | Number of Sessions and Duration | Age (yrs) | Participants per Session | Subject Matter |
|----------------------------------|--------------------------|--|-----------|--------------------------|---|
| Public Understanding for Science | 43 | 5 sessions: Same 3 hour session repeated with different participants | 14-16 | 8-14 | Part 1 of session Antarctic remote sensing |
| [university campus] | | | | | Part 2 of session urban CO monitoring |
| SENSE | 19 | 8 sessions: As series of 50 minute sessions involving same participants | 13-14 | 8 and 11 | Urban CO monitoring in school locality |
| [school campus] | | | | | |

Data Sources

In this paper we focus on questions around the production of innovative learning experiences. Here we systematically identify and analyse the ‘hidden work’ that went into these projects. As our initial project focus was on the learning sessions themselves and exploring the nature of children’s and teacher’s interaction with ‘novel’ technologies, we did not set up a priori data collection methods to capture the level and type of effort. However, a large amount of information relating to the activity surrounding our e-Science sessions was nonetheless captured. This data exists in the form of emails (of the order 520+); instant messaging (IM) logs (of the order 65+ messages); electronic and paper calendars, schedule documents, meeting notes, to-do lists (of the order 120+ documents); session videos (of the order 30 hours) and other paper and electronic documents collected over the 17 month period, in addition to our memories.

Data Analysis

Somewhat like archaeologists, we searched for, identified and interpreted relevant data in the archives of the two key researchers who were employed to work on the projects. We undertook a retrospective analysis of their project-related documents and communication trails, combined with reflective accounts of all the researchers involved in the process as participant observers.

Both of the researchers collated all available *documentation* relating to each of these projects. In the case of electronic documents, the search was greatly facilitated by recent innovations in desktop and email search applications (e.g. "Apple Spotlight," 2008; "Google Desktop Search," 2008). These applications helped recover documents containing keywords relating to these projects, created around the time periods these projects were happening and authored by parties involved. Having identified the relevant documentation we summarised the work they mentioned and any specific resources and skills referred to or implied. Often such documents prompted recall of related work that was not explicitly documented; if this related work was validated through discussion then we included this remembered work in our inventory. We excluded work that did not directly contribute to the delivery of the educational experiences, for example, the effort involved in supporting our own research goals e.g., the set-up and analysis of video and audio recordings for research purposes, discussions about methodology, etc.

This documentation was then collated as a single inventory of work across key researchers and the two projects. As a retrospective account, we do not claim it to be complete or comprehensive. We did not, for example, include the work of the project leaders as much of their involvement was around the shaping of the research itself rather than the delivery of the experience ‘on the ground’. Nor do we have access to data from others involved in the project beyond the time we spent with them, such as the teachers and ICT support officers at our schools, or the scientists, researchers and teachers at other sites that we used for remote collaboration sessions. As such, data that we present here, at least in the quantification of the work, should be read as indicative, and it could also be read as conservative.

The analytical approach then was similar to the methods of Grounded Theory (Glaser & Strauss, 1967) and using affinity diagramming techniques (Beyer & Holtzblatt, 1998) where we looked for emergent patterns in the data and created higher levels of categories to account for these patterns. As a first pass, we analysed all the items to identify key issues they indicated, for example, items that pointed to troubles getting the technologies to work. We also clustered and categorised related items in terms of achieving a specific e-Science session objective. For example, it became clear that one of the key objectives was getting an expert to participate remotely in a particular session and that various items of work were related to this e.g., making contact with that expert, sharing expectations about what would happen in the session, establishing availability, checking available technology for communication. We undertook a further level of category clustering and identified six major categories that worked across both projects. We stopped when these categories (elaborated in Table 3), appeared to be at a useful level of granularity and satisfactorily covered all the kinds of work performed in detail.

For each major category of work we will detail the main issues experienced and provide examples of the kind of work included, the participants, skills and other resources involved. In order to reveal the amount of collaboration required by some categories of work we also indicate the number of related communications (email, chat sessions, telephone conversations, etc.) as a summary table. Where individual communication items refer to several different kinds of work they are counted in all relevant categories. For example, an IM log that reports problems with a device

and arranges return of the device counts once in Equipment Management and once in Technology Testing, Breakdowns, Fixes. We also provide an estimate (indicated by +/-) for the amount of effort in person hours we believe we expended for each category and as suggested by the times of the documentation and our subsequent analysis of and reflection on them. Contributing to this, and to provide a realistic estimate of the work involved in an average communication such as an email or a phone conversation, we agreed an estimate time for each where length of time was not specified in the document (Table 2). This allowed us to develop a consistent assessment of the time requirement for the work involved in the two projects by totalling the communication, preparation and document work in each category, preserving the similarities and differences that occurred depending on the context of use (university or school); and the consequential level of control over ICT equipment. While inexact, these time estimations still provide a reasonable indicator of the relative amounts of effort expended in each category.

Table 2 - Time estimate of communication method used across projects

| Communication method | Time estimate |
|-----------------------------|----------------------|
| Email construction | 10 minutes |
| Face-to-face meeting | 45 minutes |
| Instant message chat | 15 minutes |
| Phone conversation | 10 minutes |

During the analysis for each work category we also subdivided specific work items by temporal order, according to whether they occurred prior to, during or after the sessions. There is a clear logical distinction between preparatory work required before a session can happen e.g., plan session, obtain, charge and test equipment; work during sessions e.g., facilitate learning, fix technology breakdowns; and follow-on work required after some sessions e.g., process data, evaluate. For the SENSE project, work required after sessions is particularly relevant as each session followed on from the previous one and frequently made use of its outputs. It was consequently important to maintain cross-session continuity. A further reason for subdividing our description of work in each category by temporal occurrence related to the practicalities of carrying out such work; there are potentially very different pressures and resource contexts before, during and after sessions e.g., in the classroom, at home, in the staffroom. Non-teaching work required during a session is likely very much more costly for a teacher than pre or post-session work as, ideally, as much as possible of her effort during a session should be dedicated to facilitating learning. Prior to or after a session different resources are available and work done is under less pressure, not in view of learners and in many cases might be taken on by someone other than the teacher e.g., ICT support technicians. The temporal order of activities will also be represented in the tables for each of the categories we discuss below.

Results: Categories of Hidden Work

In the following discussions we will elaborate on the definition of each category and the sub-categories of work that these entailed together with a discussion of the issues that we identified in each. To contextualise this discussion, we first present a summary of the resources used in both projects (Figure 2), and a summary of the complete set of work categories across both projects (Table 3). Figure 2 shows the relationships between projects, people and resources, and whilst many resources were used by both projects, not *all* example resources within each category were used by both projects. For example, the SENSE project collaborated with one remote scientist and the G&T project collaborated with five.

Table 3 as a summary of the complete set of categories, shows the relevant distribution of effort across the categories and illustrates that locating and/or creating contextualising material and testing, breakdown and fixes together constitute 72% of the effort.

We now go on to discuss each category and sub-category in turn, drawing in reference to the people and resources as relevant.

Match Learning Requirements

‘Match learning requirements’ is concerned with ensuring that the design of the sessions was in line with the learning needs of the students and was supported by the teachers. There were three major sub-categories here: relationship

building and collaborating with teachers; establishing the main goals of the sessions; and planning and refining the activity sessions. Table 4 shows how the resource allocation differed over both projects, for example SENSE researchers visited an after-school club to trial activities. Post-session feedback was particularly important for the G&T sessions since they were refined and repeated over time. We describe the main issues arising from these aspects of the projects in the following section.

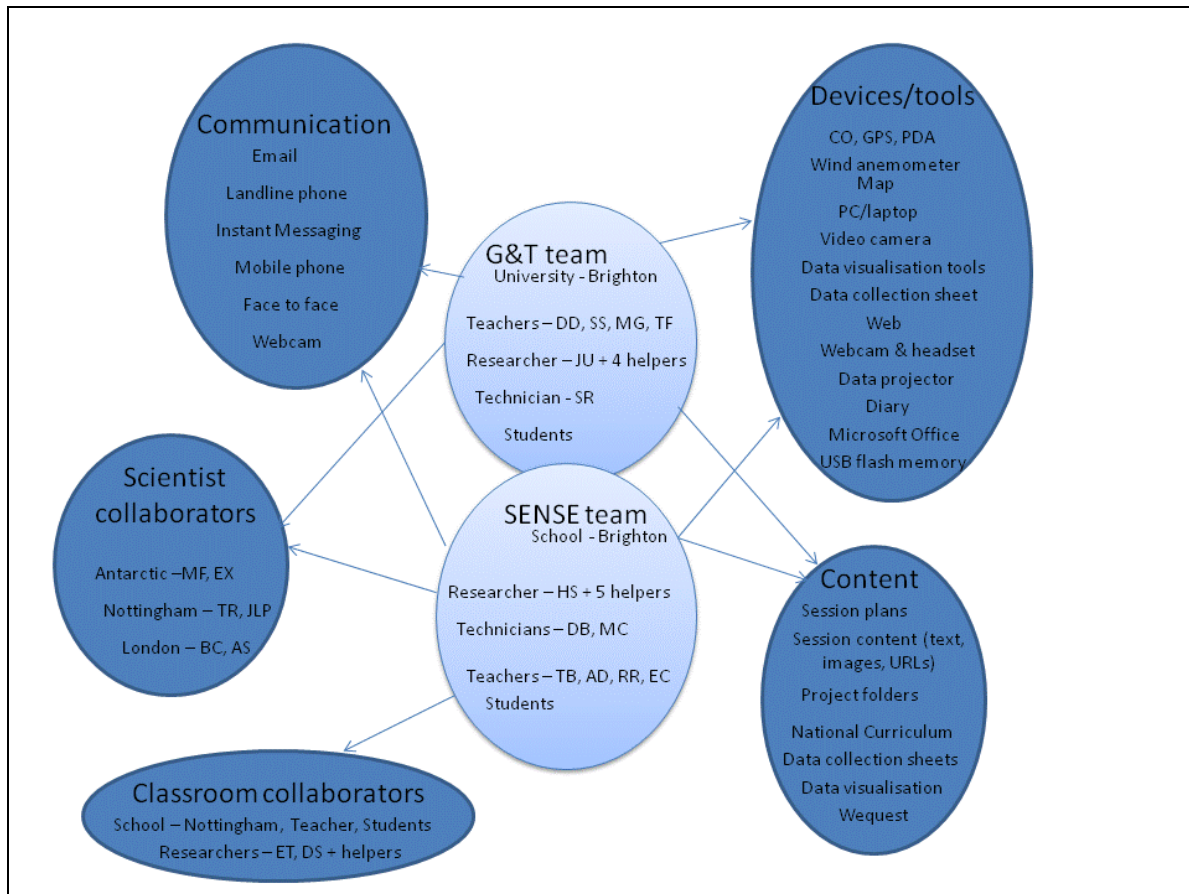


Figure 2 - Summary resource diagram showing people and resources used by each project

Relationship building and collaborating with teachers: Collaboration with science teachers at early stages was required to identify a fit with science curriculum topics, learning objectives and the learners' needs and abilities. It was also required to build understanding and trust between researchers and the people responsible for the learners involved. The work here required knowledge of the e-Science research projects and an expertise in education. We relied heavily on our participants' access to and familiarity with email and web browsing although in our experience teachers frequently have problems with school email, and messages are quite often reported as not having been received. We also had problems trying to schedule mutually suitable times to meet with the teachers because of timetable and school activity constraints.

*In Underwood et al. (2008) we combined scientist and classroom collaboration in the discussions under this category. Here we keep the detail of these different types of collaboration (remote scientist, remote classroom) as these have implications for how one might want to include them or trade-off relative effort in the design of a new experience. Presenting it in this way preserves the detail to enable more informed design decisions.

Establishing the main goals of the sessions: Substantial communication was required to establish a clear understanding of the teachers' objectives for these sessions, and for the teachers' an understanding of the e-Science research projects and the opportunities for learning these afforded. Our projects' session goals were to match curriculum requirements for hands-on data gathering, data review and ability to re-visit and improve on data gathering (SENSE) and engaging and stretching able learners throughout the session and prompting them to reflect

on the nature of e-Science and new technologies in the service of science (G&T). The researchers were able to identify relevant areas of the science National Curriculum that would point to the necessary learning outcomes and skills, but it was the teachers who were able to advise on how to apply goals to the sessions we wanted to create.

Table 3 – Summary of hidden work categories

| Work category | Sub-categories | Total time estimate |
|--|--|---|
| Match learning requirements | <ul style="list-style-type: none"> - Relationship building and collaborating with teachers - Establishing the main goals of the sessions - Planning and refining the activity sessions | +/- 16.5 person hours G&T +/- 20 person hours SENSE 8% of total |
| Locate and/or create contextualising materials | <ul style="list-style-type: none"> - Preparation of introductory materials - Sharing resources - Tracking session progress | +/- 105 person hours G&T +/- 96.5 person hours SENSE 47% of total |
| Co-ordinate collaboration and communication* | With science experts: <ul style="list-style-type: none"> - Initiating contact with relevant scientists - Scheduling sessions with a scientist - Managing and maintaining the scientist relationship With collaborating classroom: <ul style="list-style-type: none"> - Scheduling sessions with the remote classroom - Managing and maintaining the classroom relationship | +/- 13.5 person hours G&T +/- 9 person hours SENSE +/- 3 person hours SENSE only 6% of total |
| Data manipulation | <ul style="list-style-type: none"> - Transfer CO and GPS data - Process data to apply it to a visualisation tool - Make data available for others to view | +/- 4.5 person hours G&T +/- 36.5 person hours SENSE 9% of total |
| Equipment management | <ul style="list-style-type: none"> - Equipment sourcing and scheduling - Determining needs of the equipment - Ensuring good health of equipment | +/- 10 person hours G&T +/- 12 person hours SENSE both figures exclude travel 5% of total |
| Testing, breakdowns and fixes | <ul style="list-style-type: none"> - Installing and testing software on PCs and laptops to be used in sessions - Requesting support from school ICT technicians - Troubleshooting in-session and on-the-fly | +/- 33.5 person hours G&T +/- 72.5 person hours SENSE 25% of total |
| | Total time for G&T Total time for SENSE | +/- 183 person hours +/- 249.5 person hours |

Table 4 - Resource summary for match learning requirements

| Example types of work and when they occurred relative to the session | Participants involved | Resources involved | No. of communications | Total time estimate per project |
|--|--|---|--|--|
| Pre: Face-to-face meetings, email exchanges to identify learning requirements; curriculum goals. Design activities for low-technology devices and visualisation tools. Teacher time to provide feedback on plans. School planning and timetabling discussions. | 7 teachers 5 researchers, two of whom were present at all sessions and two more provided behind the scenes support. | Email Planning documents Device plans National Curriculum information Device prototypes Research project information Prototype lesson materials | 56 emails 13 face-to-face meetings 5 phone calls | +/- 16.5 person hours for G&T +/- 20 person hours for SENSE |
| In: “Teaching work” modifying session structure and pace to adjust to learner needs. | 1 after-school science club | | | |
| Post: Face-to-face meetings and email for post session feedback, improvements. | | | | |

Planning and refining the activity sessions: Part of the work involved in creating a cohesive series of SENSE activities included trying out session formats with an informal after-school science club. Examples included using a windsock and ribbons to determine wind direction and derive where the CO monitor should be located to record CO readings. This was an iterative process involving presentation of the e-Science research and devices, conversation and reflection around evolving session plans and prototype materials. For both projects, session teachers were also particularly keen to include activities they felt would be motivating such as communicating with ‘real’ scientists, and hands-on use of advanced technology. The need to keep individual learners engaged and challenged throughout sessions meant that some work was done within sessions by adjusting plans, varying pace, or pushing faster working learners. Between sessions teachers and researchers reflected on what had worked and what had not worked and adjustments were made to materials and plans for future sessions.

Locate and/or Create Contextualising Materials

‘Locate and/or create contextualising materials’ is about the development of the core learning content of the science sessions. Creating these materials constituted by far the largest category of time (47%) and resources; it required the researchers’ time and skills to design and create the materials, and evaluative feedback from teachers and input from domain experts. The resource summary is given in Table 5 and shows the range of applications used to create resources, particularly for the interactive webquest. The repeat nature of the G&T sessions and the development series of the SENSE sessions both brought with them three main challenges as described in the following section.

Table 5 - Resource summary for locate and/or create contextualising materials

| Example types of work and when they occurred relative to the session | Participants involved | Resources involved | No. of communications | Total time estimate per project |
|---|---|---|--|---|
| Pre: Searches and requests for images and information, and context materials from a scientific data collection project. Class lesson preparation Develop and test Webquest and paper-based materials. Website development to report class activity. Organising within school timetable. Post: Implementation of suggested changes. | 4 teachers 8 researchers, 6 of whom provided occasional session or material support 5 scientists provided occasional expert advice 1 class group | Google Macromedia Flash Dreamweaver Webquest guidelines Email Telephone Face to face meetings MSN chat Word documents Lesson plans Trial plans Paper folders Powerpoint | 130+ emails 6 IM chats 12 phone calls 3 face to face meetings | +/- 105 person hours for G&T +/- 96.5 person hours for SENSE |

Preparation of introductory materials: As an example, an interactive ‘webquest’ (see <http://webquest.sdsu.edu/designsteps/index.html>) was developed to challenge students and structure their research during the one-off sessions. Resource production required specific expertise e.g., HTML, Flash and web publishing, online resource search skills and learning how to structure webquests. Production of these resources was iterative, they were evaluated by teachers and adjusted in line with the feedback received.

Sharing resources: Development of a CO familiarisation activity required search for and identification of suitable information websites as well as preparation of the students’ worksheets themselves. However, the outcomes of some of this work e.g., good CO information websites, were shared and reused across the SENSE and G&T sessions saving some effort in later phases.

Tracking session progress: Considerable effort was placed in ensuring the two collaborating classrooms conducted similar projects, at similar times, using related equipment to facilitate understanding by each group of the other group’s data, environmental context and equipment. To help maintain a coherent session structure across the series of SENSE sessions, a project-based website tracked progress through the 8 sessions. This helped the researchers in the collaborating classrooms maintain contact with progress and for students to review their activities. Continuity

also had to be maintained to match correct data to the groups who had collected it, aided by the use of consistent groups and of physical project folders in which the groups kept their work.

Co-ordinate Collaboration and Communication

‘Coordinate collaboration and communication’ was the work required to manage the relationships with the external collaborators, a core theme for e-Science methods. Here we have dealt with two similar but distinct areas of work to indicate how the required time and skills varied depending on whom these collaborators were: science experts or classroom collaborators. Two categories they both shared were initiating contact with relevant parties and maintaining the relationships.

Co-ordinating with Science Experts

Collaborating with real scientists working on similar projects to those that the students themselves were working on – here Antarctic and pollution scientists – was a potentially highly-engaging aspect of the e-Science sessions. As such, we placed a high level of importance on arranging, managing and keeping the contact between the students and remote scientists. The effort here related to scheduling time, relationship building and expectation setting with the scientists. The summary in Table 6 highlights the higher number of scientists participating in the G&T sessions (5) compared to 1 for the SENSE groups.

Table 6 - Resource summary for co-ordinating with science experts

| Example types of work and when they occurred relative to the session | Participants involved | Resources involved | No. of communications | Total time estimate per project |
|---|--|---|--|---|
| Pre: Introductions and requests for collaboration. Scheduling collaboration opportunities. Requesting and providing information. Asking difficult questions raised. | 2 researchers 6 scientists: from Antarctic - 1 environmental scientist, 1 engineer; from UK - 2 environmental scientists, 1 computer scientist, 1 pollution scientist | Email MSN messenger Telephone Diary Planning spreadsheet Data photos Scientist’s slide-show Scientist’s website | 70 emails, more than 30 chat sessions, 7 phone calls | +/- 13.5 person hours for G&T +/- 9 person hours for SENSE |

Initiating contact with relevant scientists: We were able to identify and contact suitable science experts to engage in the sessions through our close involvement in the Equator e-Science research projects. From colleagues’ recommendations, scientists were approached for their interest in our projects. Part of this work involved informally establishing that each of the scientists were known to other researchers that we knew, and checking they were sufficiently reputable to be involved in direct communication with young students.

We ascertained with each scientist what their session involvement would be beforehand to manage their expectations and prepare them for any foreseeable problems, e.g. technology breakdown. Contingency plans were mentioned at this stage, and in some cases we ‘rehearsed’ a simulated learner chat with our scientists in the chat environment to prepare for the kinds of questions we expected the students might ask. We needed to ‘present’ our science experts to learners and teachers, and some work and communication was required to obtain photos and short texts describing who the experts were, where they were located and what they did.

Scheduling sessions with a scientist: School timetables were our main time constraint on both projects since the students were only available at specific times. In contrast, our scientists had varying degrees of flexibility in their schedule and it was important that we had a variety of scientists to choose from, should one not be available. Establishing time slots for live chat between scientists and children required several emails; sometimes working across time zones. Antarctic times were particularly challenging and on one occasion failing to take into account a move to Summer Time in one zone but not the other resulted in a missed chat session. It was rare to have a back-up

scientist in-case the first was not available, but on this occasion we worked more ‘chat’ between expectant students and another remote scientist who was scheduled in.

Managing and maintaining the scientist relationship: In addition to the setting-up of scientist contact prior to live chat sessions between experts and learners, we needed to communicate to experts whether they were in a ‘private’ chat visible only to the researchers and teachers or whether the chat was currently displayed (via a data projector) and visible to all learners. This ensured comments not intended for learners or inappropriate language was not publicly visible.

Post-session, we thanked the scientists, and explained any technology failures or disruptions that would not have been detectable through the communication channel. At one school we eventually resorted to a one-to-one telephone instead of the IM software we had previously successfully used at our university, because such software was blocked on the school network and the conference phone we brought into school was incompatible with the school phone system. Such ICT problems are frustrating and waste time both at the school and the remote scientist’s end with apologies and updates on changes to the schedule and technology. On the missed slot due to Summer Time changes, additional communication was required post-session to resolve why the slot had been missed and to ‘patch up’ relations.

Co-ordinating with Collaborating Classroom

In the SENSE project, collaboration also involved a remote classroom and was set-up to provide two classes of students, unknown to each other in advance, an opportunity to communicate about the science project they had both been conducting. The major work areas are summarised in Table 7 and described below. Technology co-ordination was required for data file sharing to ensure researchers at both locations could download each other’s data prior to the live chat, and this is detailed in the ‘Data manipulation’ section.

Table 7 - Resource summary for co-ordination and collaboration with collaborating classroom

| Example types of work and when they occurred relative to the session | Participants involved | Resources involved | No. of communications | Total time estimate per project |
|--|-----------------------|--------------------------------|-----------------------|---------------------------------|
| Pre: Discussing scheduling. Planning in-class phone chat. | 3 researchers | Email | 3 emails | +/- 3 person hours for SENSE |
| Post: Thanking remote classroom. Providing feedback. | 2 school classrooms | Telephone Diary schedule | 1 phone call | |

Scheduling sessions with the remote classroom: Scheduling and planning around school timetables with the classroom teachers was performed via the researchers, who were already communicating regularly. The scheduling of the live communication session was eased by a more flexible time-table in one (primary) school to allow this session to work. Had this not been the case a more complicated planning stage would have been necessary time-table changes needed to co-ordinate the session.

Managing and maintaining the classroom relationship: In contrast to setting a collaboration session up from the beginning, there was less need here to establish detailed expectations to the same degree as had been required for the scientists’ contact. We were able to capitalise on the researchers being in contact and previously agreeing on project requirements and timescales during the school-term as part of the research activity. However, the pitch of the session did need to be managed since our classrooms were not the same age group: one was a top-primary group (10-11 years), the other being a GCSE group (14-15 years).

Data Manipulation

A main focus of e-Science methods is the ability to share, visualise and reflect on data rapidly. ‘Data manipulation’ includes the work required to integrate, collate and visualise the information gathered by the students on their different devices. In our exploratory sessions, there were no simple ways to join-up the technologies so that each piece of hardware could automatically transfer data to a central hub or data store and be immediately available to our

collaborators. We therefore had to manually transfer and edit the data to allow, for example, visualisation of a remote data set (Antarctic lake ice depth data), analysis of the CO data against initial expectations, and sharing the data with others. The large difference in this work between the projects is summarised in Table 8 and reflects the work involved in maintaining continuity for each small group to access their data in subsequent SENSE sessions.

Table 8 - Resource summary for data manipulation

| Example types of work and when they occurred relative to the session | Participants involved | Resources involved | No. of communications | Total time estimate per project |
|--|---|---|---|---|
| Pre: Learn how to transfer data from sensor device, and into visualisation tools Connectivity with class and scientist In: Transfer data: from mobile sensor to PC, upload to web visualisation services. Download data from Antarctic device web data service, import into Excel. Post: Prepare data for collaborator sharing | 4 researchers Students involved in sessions. | Excel Web-based service interfaces Data transfer software Laptops Web site for private data sharing Emails, IM chats | 56 emails 10 instant message chats | +/- 4.5 person hours for G&T +/- 36.5 person hours for SENSE |

Transfer CO and GPS data: Data transfer between the mobile data-storage device and the PCs used back in the science lab was necessary for the visualisation activities to occur. Prior to the sessions we needed to learn how to navigate the PDAs with PCs, how and where the sensor data files were stored and how to transfer them to the PCs in the absence of a network.

Process data to apply it to visualisation tool: For our one-off sessions, once provided with their data on their own PC, the learners were able to upload data for processing and visualisation via a web-service and load and graph it with no need for non-teaching work by teacher or researchers. The data processing for the SENSE project needed to occur between sessions e.g. transfer of the collected data from PDAs to project laptops, the video recordings from tape to hard-disk, time-synchronise the video with collected data, and transfer to laptops for children to review in the data-analysis sessions. Students' data annotations were checked before being shared with the remote class students to ensure appropriate for viewing by other children.

Make data available for others to view: Sharing data happened within class groups for both projects, and across school classes on the SENSE project. Within class, the sharing of data via a USB memory drive was time consuming but meant we were easily able to provide every group with other groups' data should they have the opportunity to compare data. Across schools, a sample of data was made available on a private website (meaning the data's use could be protected) for download by the collaborating class prior to the live phone conference.

Table 9 - Resource summary for equipment management

| Example types of work and when they occurred relative to the session | Participants involved | Resources involved | No. of communications | Total time estimate per project |
|---|--|---|---|--|
| Pre: Schedule loan and collection of devices from 'owners' Order video tapes Post: Return to 'owners' Explain issues: broken sockets, problems, questions. | 4 teachers, 7 researchers, 2 device 'owners' | Mobile sensors (PDA + GPS + CO Sensor) Anemometers Low tech sensors | 57 emails 6 chat sessions 8 phone calls | Excluding travel time: +/- 10 person hours for G&T +/- 12 person hours for SENSE |

Equipment Management

'Equipment management' is concerned with the sourcing and loan of the equipment from research scientists. The technologies were fundamental to the success of our e-Science sessions since without them we would have struggled

to provide such an engaging hands-on e-Science experience. This work required no special skills but did require substantial communication, negotiation and organisation effort and relied heavily on our relationship with the equipment providers. The work involved here, summarised in Table 9, was fairly even across both projects.

Equipment sourcing and scheduling: We had relatively good access to the devices used in these sessions as a result of our research relationship with the device owners. We needed to communicate extensively to establish when they could be used, negotiate for pick-up and return dates, and how they would be transported between sites.

Determining needs of the equipment: The equipment was not accompanied by a 'How to use' handbook, and thus we became familiar with the equipment through establishing the requirements for the loaned devices, chargers, cables for data transfer, etc. and ensuring we had adequate access to all of these, in particular sufficient chargers.

Ensuring 'good health' of the equipment: Since we were very dependent on the equipment providers for continuing the projects it was imperative that the equipment was treated with respect and any problems reported when known - both by the researchers and equipment owners. This honesty was appreciated by both parties and kept the equipment at maximum productivity.

Testing, Breakdowns and Fixes

'Testing, breakdowns and fixes' is closely related to equipment maintenance and repair as well as more general infrastructure issues. This category of work required as much pre-session preparation as necessary to install and run software required for all parts of the sessions, and is summarised in Table 10. The higher workload for SENSE indicates differences between running sessions in a university lab and a school lab, with different access to IT resources and permissions to run software as detailed below.

Table 10 - Resource summary for testing, breakdowns and fixes

| Example types of work and when they occurred relative to the session | Participants involved | Resources involved | No. of communications | Total time estimate per project |
|---|---|---|---|--|
| Pre: Charge, test sensor and recording equipment. Refer to owner to resolve problems. School IT department liaison. Load and test communications software | 3 technicians - 2 in school, 4 researchers, 2 computer scientists (developers of borrowed equipment), 1 school Head of IT | Mobile sensors, PCs, Laptops, Software, Telephone, Mobile phone, Email, Skype, Netmeeting, Conference phone | 150 emails 13 IM chats 13 phone calls | +/- 33.5 person hours for G&T +/- 72.5 person hours for SENSE |
| In: Troubleshoot breakdowns. | | | 5 in-school trials with school IT support | |
| Post: Record any issues with borrowed equipment for reporting to owner. | | | | |

The two projects varied in their locations: G&T sessions were held on a university campus where researchers had more control and more on-site pre-session time to organise equipment; the SENSE sessions were school classroom based with university laptops interfacing to the web via the school network. This strategic move to use the university laptops in school provided an increased confidence that the equipment would be available, resulting in substantial preparation and post-session time-savings and ensuring that most of the software would work with minimal room access pre-session. The main factors in this category of work were therefore installing and testing software, requesting support from ICT technicians and troubleshooting on-the-fly.

Installing and testing software on PCs and laptops: Across both projects much of the effort was spent testing and installing software on the PCs available for use in the sessions. Some activities could be performed in advance e.g. check web resource locator addresses and 3D data visualisation plug-ins are installed and up-to-date; add software to facilitate transfer of data and for live collaboration links; test applications in-situ e.g. connection for collaboration sessions on school network.

The kinds of issues that arose in this preparation work included the need to find a free Virtual Reality Modeling Language (VRML) plug-in that would work with the low specification PCs available for use in sessions, and testing IM software on the school network. Our in-school IM trials were unsuccessful and led on to a backup plan of using a phone, and it was here that we discovered a trade-off between familiar equipment and compatibility of software with the school network under pre-session set-up time pressures. Added complications included the variety of computer platforms in use, scientists preferring a more familiar application and variation in access and networking infrastructures at schools and universities.

Requesting support from school ICT technicians: Surprisingly, co-ordinating and testing the phone equipment in the school science lab needed expertise from the school's phone technician. For example, an unconnected phone socket was temporarily 'opened' for the school collaboration session and tested with the remote school in advance of the session. Our testing used mobile phones to communicate between researchers and revealed further issues about which school could call the other, depending on the institution's phone line permission policy for making local and national calls. We found a conference phone used at the university was incompatible with the school's phone system, an unexpected complication from a tried-and-tested technology.

Troubleshooting in-session and on the fly: We experienced a large number of in-session technology breakdowns. For example, during some sessions a video and audio conference was attempted, but despite successes in earlier tests the sound failed at one end. We attempted to 'fix' the connection before resorting to text chat accompanied by live video. We also needed to prepare, and in the event had to use, back-up technology in the cases where planned technology failed e.g., the telephone call to a scientist, which in turn required the experts' phone number and a working phone line in the classroom. We invested time resolving trivial breakdowns with the unfamiliar sensor equipment, e.g., how to turn the PDA sound up, how to 'wake' the screen up, and the need to wait for GPS satellite pickup during bad weather.

Summary

In this section we presented a discussion of the analysis of categories of work, and effort and resources required to undertake that work. The chart below (Figure 3) gives a visual indication of the proportion of time spent on the hidden work categories across both projects.

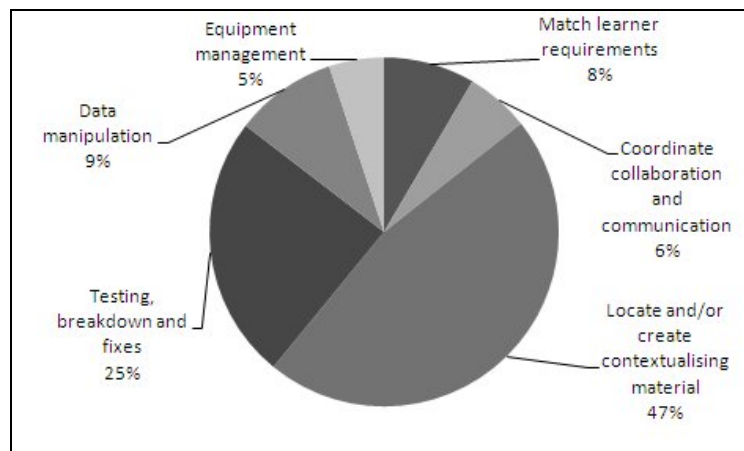


Figure 3 - Distribution of work across all categories

Discussion

Alsop and Thompset (2007) suggest that educational researchers must track and quantify the additional resources available in research contexts as they move from demonstrating effectiveness for learning to efficacy and efficiency in real contexts and furthermore they suggest that this is a necessary demonstration if educational practitioners are to be expected to adopt innovative practice from research. In this paper we identified the hidden work required to deliver novel technology enhanced learning experiences and suggest that through analysis of this work we can move

towards delivery of similar experiences in real world educational contexts. Analysis of our own experiences in running e-Science experiences in semi-realistic contexts indicates they involved a significant amount of ‘hidden work’: conservatively, we have estimated 183 person hours to re-run the same session 5 times (G&T) and 249 person hours to run a series of 8 sessions (SENSE). This order of effort is beyond what is usually practical within teachers’ limited lesson planning time.

Further our analysis reveals the variety of skills required not only to understand the science content and pedagogical aspects of delivering this but also technical issues: from ‘mundane’ communications infrastructures (the internet and phone), to PC-based off-the-shelf packages which none the less required significant effort to install and troubleshoot, to more cutting edge sensor-based devices and GPS infrastructures, and to understanding how to integrate data from diverse sources for manipulation and display.

While much of the effort here is admittedly due to these projects still being at a research stage and making use of a user-centred and participatory approach, it nonetheless points to the significant areas that would need to be attended to if teachers are to take on the design and delivery of such experiences. Hence a principle contribution from this work has been the systematic identification, through retrospective analysis, of the key categories of work involved in delivering these experiences, as summarised in Table 3, and of the people and resources involved, as summarised in Figure 2.

Limitations of the methodology

Bringing further data to bear on the work categories and framework will be important because of the limitations of our own methodology. We necessarily used a post-hoc collation and analysis of data because of the emergent nature of our understanding of the issues. While the order of effort involved in creating and running the e-Science G&T and SENSE sessions gradually became apparent to us over the course of the projects, it was only during our post-experience reflections that it became obvious exactly how these kinds of experiences are currently way beyond the reach of teachers due to the order of effort involved.

As such, the methodology we employed has a number of limitations: because we did not collect accurate data about the work at the time there will necessarily be some inaccuracy in accounting of effort; we needed to double up on some of our effort because the SENSE project was running slightly behind the G&T project sessions; and because we only had access to our own archival data we have had to omit accounting for time and resources contributed by others within the experience e.g., scientists, teachers, technicians. In addition an unknown amount of data has been lost from our datasets through the time lapse between data creation and analysis, and natural archiving and deletion activities by the researchers.

In future projects, a priori planning for the systematic capture of hidden work will be useful for both sense-checking the categories and to determine a more accurate reflection of the levels of effort involved. Some more informed ways to proceed for better accuracy in reporting this effort would be to:

- develop a time and skills resource plan based on previous experience design knowledge
- maintain reflective estimates of time spent on each category of work during the creation of an experience, identifying where changes in the new experience will save on or cost more resources
- reflect regularly on project progress and resources demanded by project progress.

Developing these ideas further we can see that a more complete picture would be revealed if all partners, i.e. researcher, teacher and scientist partners, were involved in the reporting of time, skills and resource data, and this would contribute to a team-wide, shared view of the planning and running of the educational experience.

Taking the work forward

Even with these limitations, we suggest that the categories identified in this research can be usefully taken forward in three ways: to help in planning of other e-Science learning experiences, to be further tested and evolved in future research, and as a basis for developing an overall experience framework to capture more of the process-related aspects in which these tasks are embedded. We will discuss each in turn.

Firstly, the articulation of these categories and resources can be useful as a working checklist for the pro-active assessment of future resource and skill needs when planning other learning experiences. This might result in a priori planning for how to manage each category or result in choosing to re-design an experience to manage the work, e.g., not to include a remote collaboration because of the effort involved. The categories identified in Table 3 point to the key types of work that need to be considered for e-Science experiences. However, these categories could also be tested for applicability and expanded for other kinds of technology enhanced learning experience.

Secondly, the categories as articulated can form the basis for more pro-active and a priori data collection by researchers and all stakeholders in future learning experience projects. Since the categories and orders of effort have been constructed by post-hoc analysis it would be important a) to test whether these categories hold across other types of learning experiences and to evolve or expand the categories as appropriate, and b) to collect work data in real-time to validate and expand understandings of the orders of effort involved for different types of work.

The value in doing this is that we may then be able to identify where and how we can make the process easier and provide better support to teachers in designing and running their own learning experiences. This could be through guidelines or technology toolkits (Underwood et al., 2008; Woodgate & Stanton Fraser, 2006). For example, if it is confirmed that coordination with remote collaborators is useful from a learning perspective but takes significant time and resources, we could look at developing a skills directory with associated scheduling tools to make it easier for a teacher to identify a science expert and schedule a class session with them.

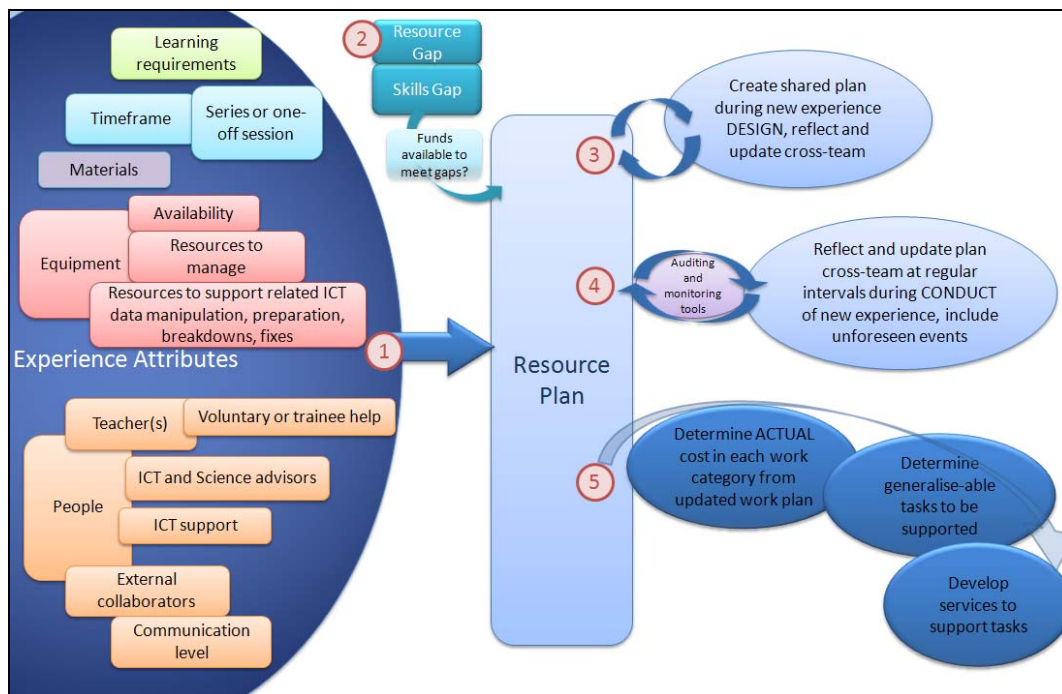


Figure 4 - Experience framework, to plan and analyse e-Science educational experience resource needs (numbers reflect proposed phases of an experience)

Thirdly, we can also use the understanding of the categories, the people and resources involved to develop an overall 'experience framework' to guide the planning process. Koszalka and Wang (2002) emphasise the need for practitioners to consider their learning context when planning technology integration, and for technology developers to gain a better understanding of the challenges of teaching environments. To this end, the experience framework (Figure 4) illustrates the resource and skill implications of technology enhanced educational experiences in school contexts, based on our understandings to date. The formulation of this framework derives from our resource diagram, Figure 2, and categories of work, summarised in Table 3. In pulling together a coherent resource plan for new educational session(s), phase 1 is labelled 'Experience Attributes', it covers the hidden work categories we identified and provides a checklist of all the items we found necessary in our sessions' design, set-up and delivery. The phase 2 items of 'Resource gap and Skills gap' were derived from our data analysis of potential skills and resource shortages

within a teaching unit, and indicate where external skills may be bought in, trained up, or requested from an ICT support unit if funds allow.

Phases 3-5 on the right-hand side of the resource plan indicate how an iterative cycle of session development across team members is created, and could also be validated either by practitioners or by practitioners and researchers. Phase 3 thus results in revisions of the resource plan as a session design is negotiated and agreed with colleagues and potential collaborators e.g. through new knowledge of equipment hire costs, or availability. For additional assessments of hidden work phases 4 and 5 may be performed by researchers or practitioners if data is planned to be collected in an a priori manner.

We propose the ordered phases required for teachers, scientist collaborators and other session planning colleagues to firstly 'build a Resource Plan' for a learning experience comprises the following, as indicated by numbers in red circles in Figure 4:

- Produce an initial resource plan based on the desired attributes of the educational experience at the outset. The experience's timeframe and its nature (whether a one-off session or a series of sessions) are examples here. This initial plan should involve as many intended team-members as possible e.g., teachers, ICT and science technicians, school policy advisors, scientist contacts if known.
- From the initial plan, the identified skills - or resource-gaps - e.g. a lack of science or communication equipment, must be solved through the funds available to meet this gap.
- Iterative development of the design of the experience across the intended team members is then put in place to ensure each team-member has a shared ownership, and equal contribution to the plans.

At the end of phase 3, teachers, along with any collaborators, should be equipped to deliver on the session design, as defined within the constraints of available resources. The practice of review and reflection on technology enhanced teaching can also provide valuable training opportunities. Dawson and Dana (2007) advocate using 'teacher enquiry' as: "a strategy for helping educators systematically and intentionally study their own practice, [and] provides important benefits for prospective teachers participating in curriculum-based, technology-enhanced field experiences" (Dawson & Dana, 2007, p. 656) particularly in challenging perceptions about teaching with technology. Here, for practitioners and/ or researchers to secondly 'review the resources' involved in the session's design and delivery, an audit process, set-up a priori to capture the data for the work categories specified by our data analysis, would use phases 4 and 5 of the framework:

1. During the conduct of the experience plans, the team keeps concurrent records and reflections on skills, time and resources used to feed into phase 5. Communication and time tracking tools that create a shared log of activities can be used from other professions e.g., legal project tracking, or recording tools developed for ethnographic support (Iacucci et al., 2004; Morrison et al., 2006).
2. The final phase, and longer term objective, works towards the identification of generalisable tasks or technology packages from the whole experience, combined with data from experiences others create, that can be better supported by a suite of computational or other support services for teachers, technicians, scientists and others or the development of technology toolkits for the classroom (Underwood et al., 2008) to assist further collaboration.

We have suggested that the work categories and experience framework can be used as a basis for guiding data collection of hidden work in future projects so that they can be evolved to account for more diverse technology enhanced learning experiences. Hence, we present these categories and the associated framework as a starting point for others to engage in this reflection and planning process, and further refine the model depending on the various parameters of their own educational experience design.

Conclusions and future work

Many reports of novel technology enhanced learning projects account for the learning experiences of the students and point to the exciting potential of new technologies to enable engaging hands-on learning but tend to delete from their accounts the work involved in delivering those experiences. We have used the term (from elsewhere) of 'hidden work' to describe this work to put the experiences to work. It is the understanding of this work, and being able to develop the tools and processes to support this work, that will make the critical difference to moving e-Science in the classroom out of the hands of researchers into the hands of the teachers.

To begin this process, we have provided a retrospective account of the effort involved in delivering on two education e-Science projects. From this account, we have suggested that the identified work categories can be used as an experience checklist. We have also included these categories into a broader process-oriented experience framework that can be used as a planning tool. We present the categories and framework for trial and critique by science researchers, educational professionals and others in order to further its development as a methodology for assessing and analysing the types of hidden work we have identified. We believe collecting real-time records of effort will contribute significantly to this aim. As such, we anticipate its use in:

1. helping others to identify realistic costs of creating and running their own experiences,
2. developing a richer understanding of the variety of experience attributes that affect the associated resource and time costs,
3. and obtaining additional reflections from other researchers' uses to further the aim of identifying those tasks which are considered generalise-able across different experiences to warrant design, development and the refinement of support services.

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Adaptable Learning Pathway Generation with Ant Colony Optimization

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ABSTRACT

One of the new major directions in research on web-based educational systems is the notion of adaptability: the educational system adapts itself to the learning profile, preferences and ability of the student. In this paper, we look into the issues of providing adaptability with respect to learning pathways. We explore the state of the art with respect to deriving the most apt learning pathway to recommend to the learner. Our proposal suggests a novel way of modeling learning pathways that combines rule-based prescriptive planning, which could be found in many of the classic Intelligent Tutoring Systems, and Ant Colony Optimization-based inductive planning, for recommending learning paths by stochastically computing past learners' traveled paths and their performances. A web-based prototype has been developed using C# and .NET technologies.

Keywords

Web-based learning, Learning pathway planning, Course sequencing, Personalized e-Learning, Swarm Intelligence (Self-Organizing Agents), Ant Colony Optimization, Learning on Demand

Introduction

With the proliferation of the usage of Internet technologies, many learner-centric e-learning portals have been launched. To cater for working adults' needs, the notion of "Learning on Demand" (LoD), defined by SRI Consulting Business Intelligence (n.d.) as "the process of using technology to enable and encourage workers, managers, and executives to learn and acquire new skills while resolving organization's problems", has emerged. For example, if an inexperienced Java programmer needs to implement a clock Applet, she need not study the entire Java programming guide. She only needs to learn about those few relevant Java library packages plus some other prerequisite knowledge. An advanced e-learning portal should provide such flexibility for the learners based on their learning goals.

We propose Dynamic Learning Path Advisor (DYLPA), a set of course sequencing algorithms that combine both prescriptive navigation rules and an inductive mechanism. Our research effort focuses on the latter, where we propose a mechanism that is inspired by a specific technique in an agent-based soft computing technology field called "swarm intelligence" or "self-organizing agents" (Bonabeau, Dorigo & Theraulaz, 1999; Engelbrecht, 2006). Swarm intelligence comes in various forms like Ant Colony Optimization (ACO), Particle Swarm Optimization (PSO), wasp task differentiations, and so on. In particular, a modified ACO mechanism has been developed for DYLPA. The prescriptive rules, proposed by earlier researchers, form the complementary component to the induction mechanism that we propose.

The learning path optimization process starts from the launch of a new course. At the early stage, without substantial amount of learner history, DYLPA recommends a learning path based on the prescriptive rules. However, DYLPA would not make the recommendation a strict prescription and instead allow the learner to explore an alternative path at her own will. The learner's performance in learning from each object will be measured and stored.

The learners' performance logs are thus gradually built up. By satisfying certain condition, the induction mechanism is triggered. When the next new learner logs on, the system will select up to a specific number of previous learners (or "alumni") who have similar profiles. The paths they have taken and their performances are analyzed by the swarm intelligence technique to "induce" a path for the new learner. However, the "prescriptive path" is not totally discarded. Instead, it is treated as a "virtual learner's" choice of a path that carries certain weight in the computation. Hence, the combination of rule-based prescription and stochastic computation in path selection is achieved. We believe that our approach is one of the first course sequencing techniques that explicitly combine prescriptive and inductive planning.

Literature Review

To facilitate Learning on Demand in the context of an e-learning portal, what comes into our mind is the “classic” Intelligent Tutoring System's (ITS) rule-based course sequencing techniques like Peachey & McCalla's (1986) curriculum planning techniques and Study Advisor (Arshard, 1989) where a learning path, i.e., a series of ordered learning objects, is chosen given a learning goal. One underlying weakness of the former, albeit its capability of generating learning path tailored to individual's current knowledge state, is that the navigation is based on a single rule: learn prerequisite knowledge first. The Study Advisor improves upon that by adding more metadata types (relationships between learning objects) to enable alternative path selection to suit learners with different learning styles, e.g., learners who prefer “generalization before specialization”, or vice versa.

Some variations of such techniques in e-learning environments are reported in more recent literature (Karagiannidis, Sampson, & Cardinalli, 2001; Carchiolo, Longheu & Malgeri, 2002; Chen, Liu & Chang, 2006). Carchiolo *et al.*'s (2002) system, in particular, moves away from prior rule-based planning and instead assigns weights to individual arcs (each arc links a pair of learning objects in the course topology) according to how “suitable” individual paths are for a particular learner with respect to her profile, and subsequently makes use of the weights to recommend “the next learning object” upon the learner's completion of the current one.

However, prescriptive rules are typically designed based on commonsense or expert notions of how a learning path should be chosen, which are not always valid and could be relatively rigid. Brookfield (1985) suggests an alternative approach, “successful self-directed learners... place their learning within a social setting in which the advice, information, and skill modeling provided by other learners are crucial conditions for successful learning.” The argument finds echoes in the information navigation literature, where the term “social navigation” (Höök & Benyon, 2003) has been coined to describe research reflecting the fact that “navigation is a social and frequently a collaborative process.” (Dieberger, Höök, Svensson & Lönnqvist, 2001) In particular, “indirect social navigation” exploits traces of interactions left by others and can be used as the basis of a recommendation system (Shipman, Furuta, Brenner, Chung & Hsieh, 2000).

In the light of the alternative notion, Internet-based e-learning technology facilitates convenient collection and analysis of the activity logs, the performances and the results of a large pool of learners. That opens the door for researchers to look into data mining-like, constructive induction mechanisms where the historical data of previous learners' learning paths or actual performances can serve as a basis in selecting learning paths for new learners.

For example, the Web “tour guide” agent WebWatcher (Joachims, Freitag & Mitchell, 1997) accompanies thousands of users from page to page as they browse the web, and generate a “path”, which is an ordered set of webpages, for each particular topic that maximizes the amount of relevant information encountered. Similarly, the Tutorlet agents (Niemczyk, 2000) employ Hidden Markov Models (HMMs) (MacDonald & Zucchini, 1997) to develop a statistical model of student behaviors based on past students' choices of learning paths. Such agents recommend the next learning media type (e.g., text, video, simulation, etc.) to a new student after she finishes her activity under the current media type. The e-learning portal Knowledge Sea (Farzan & Brusilovsky, 2005) works in the same way as WebWatcher except that a Time Spent Reading (TSR) (e.g., Claypool *et al.*, 2001) algorithm was used. Huang, Chen & Cheng (2007) proposes an improved approach that makes use of FP-tree technique to make multiple levels of abstract suggestions instead of single level frequent pattern mining results as its predecessors do.

Our proposed DYLP algorithm is one of the earliest applications of the swarm intelligence techniques in course sequencing that make use of past learners' performances (not just the paths they have traveled) as the basis for path recommendations. After an extensive literature search for related work, we only managed to identify four such systems (Gutiérrez, Pardo & Kloos, 2006; Van den Berg, *et al.*, 2005; Vaigiani, *et al.*, 2005; Wang, Wang & Huang, 2008). We will compare our approach with theirs in a later section of this paper.

Ant Colony Optimization and its Applications

In the natural phenomenon of “Ant Colony Optimization” (ACO), ants construct networks of paths that connect their nests with available food sources. These networks form minimum spanning trees, minimizing the energy ants expend in bringing food into the nest. This globally optimal structure emerges from the simple actions of the individual ants

(Parunak, 1997; Dorigo & Stützle, 2004). Steels (1991) proposes a model where all ants share the same set of five rules to govern their actions: Avoid obstacles.

1. Wander randomly, in general direction of any nearby *pheromones* (scent markers that many insects generate).
2. If the ant is holding food, drop food pheromone while looking for and following a beacon, e.g., nest pheromone that leads in the general direction of nest. If the ant is not holding food, drop nest pheromone while looking for and following a food pheromone trail.
3. If the ant finds itself at food and is not holding any, pick the food up.
4. If the ant finds itself at the nest and is carrying food, drop the food.

Because only food-carrying ants drop food pheromone, all food pheromone paths lead to a food source. Once a full ant finds its way home, there will be nest pheromone paths that lead. The initial path will not be straight, but the tendency of ants to wander even in the presence of pheromones will generate shortcuts across initial meanders.

The ant path planning mechanism has inspired algorithms (e.g., Dorigo, 1992; Bonabeau, Dorigo & Theraulaz, 1999) for planning routes in the Travelling Salesman Problem (TSP), i.e., to find a tour of minimal length connecting n cities; each city must be visited once and only once. In the case where the number of cities is huge, soft computing techniques like genetic algorithms or ACO become better alternatives than conventional AI search techniques in solving such a NP-hard problem.

In an algorithm proposed by Dorigo (1992), for example, a huge set of ant-like agents are moving on the problem graph until each of them completes a tour. Initially, each agent selects the next connected city randomly when it reaches one city and maintains a memory of the cities it has visited and the distance of each edge. After completing a tour, it lays a quantity of pheromone Q/L on each edge that it has used, where Q is a parameter and L the total length of the tour.

With the pheromone being accumulated, each of the subsequent agents' selection of the next city to visit when it reaches one city will be influenced by the pheromone of each corresponding edge. There is a probability factor here – the greater the value of a particular edge's pheromone, the higher the probability the agent selects the edge. This is the key mechanism to “balance exploitation and exploration” of alternative solutions, the essence of swarm intelligence, rather than exploiting the presently known best solution all the way.

The method could not perform well without pheromone decay, or it would lead to the amplification of the initial random fluctuations, which very probably would not be optimal. Therefore, the quantity of pheromone that was “deposited” earlier should be decayed as time goes by.

Some variations of TSP ACO Algorithms have also been applied to a similar problem – communications network routing (e.g., Caro & Dorigo, 1998; Di Caro, 2004; Wedde & Farooq, 2006). Such algorithms offer better results than conventional AI search techniques in handling dynamic network conditions, e.g., the optimal path now may be congested later.

From Ant Colony Optimization to Learning Paths

As described before, “conventional” learning path planning can be viewed as finding a path in a course network that leads to one or more learning goal(s), which is analogous to the destination node in network routing. As our research objective is to derive a stochastic mechanism that involves the alumni's selection of paths and actual performances, the ACO metaphor has offered a plausible and perhaps powerful solution – the pheromones.

In adapting ACO for DYLPAs, we consider a few issues:

- **“Populating” the course network.** Whereas ACO Algorithms generate simulated agents to wander about the network and measure the cost (e.g., travel time) on each edge, DYLPAs intend to “induce” good learning paths from actual alumni's performances. Therefore, in DYLPAs, each of the selected alumni is treated as an ant-like agent that moves on the course network and deposits pheromone along her way.
- **Similarity of the ant-like agents.** The ACO Algorithms always populate each search space with homogeneous agents. With this concern in mind, DYLPAs need alumni that are similar to the current learner to populate the course network so that the recommendation could tailor to individual learners' needs or preferences. However,

since learners with diversified background or preferences could be enrolled in the same course, DYLPAs have to re-select “training cases” and re-compute the pheromones each time a new learner is enrolled.

- **Where the pheromones are generated.** In many ACO-based applications like network routing, each node is only a point where agents drop by while the real performance measurement is the time spent on each edge. In a course network, however, a learner actually spends her time when attempting the nodes (learning objects) while an arc merely reflects the relationship between two nodes. Moreover, a learner’s performance at a node is often influenced by the combination and the sequence of the nodes she had visited prior to that. Therefore, the pheromone generated at a node should reflect the “goodness” of the previous arc. For example, if a learner visits node j right after node i , the pheromone generated at node j should be attributed to arc (i, j) instead of any “outbound” arc of node j . However, at which node a pheromone value should be stored could become tricky when the system needs to make use of it for recommendations. We will address this issue in a later section.
- **Whether the time-decaying feature of the pheromones should be incorporated into DYLPAs.** The reasons such a feature is incorporated in the original ACO Algorithms are :- (a) To let the earlier agents’ findings (which are essentially unguided since the pheromones have not been substantially accumulated yet) gradually evaporate; (b) To cope with the dynamic environment in certain applications (e.g., the communications network traffic).
- Reason (a) is relevant to DYLPAs in an indirect sense that when a greater set of historical data is accumulated, the number of learners that are more “similar” to the current learner tends to increase, resulting in more “accurate” pheromones/recommendations. Reason (b) is also valid in DYLPAs because of the possible updates of the course content such as addition or deletion of learning nodes, and amendment of the contents in the existing learning nodes – which is not unusual for e-learning portals in the 21st century. Such updates might affect the overall performances of “similar” learners who are enrolled in the course at different periods of time, making the previously deposited pheromones less accurate in predicting the performances of new learners.

Two important assumptions of DYLPAs are:

- There are a lot of learners enrolled in an e-course or a set of overlapping e-courses at different periods of time to guarantee sufficient “training data”; and
- Many learners are adventurous enough not to always follow system recommendations - otherwise, DYLPAs will keep on “exploiting” the prescriptive path instead of “exploring” alternative paths.

For assumption (2), the “rebellious mindset” is more likely to be found in adult learners than young students, especially if those who are attempting Learning on Demand are time pressed to accomplish their learning goals. Therefore, we predict that DYLPAs would work better for adult learning.

Learner Profiles in a DYLPAs-based System

A learner profile, the key resource for facilitating the DYLPAs process, consists of two components: (1) learner attributes; (2) activity log.

“Learner attribute” is a way of quantifying a learner’s relevant background, prior knowledge, learning preferences, and other learner information. The system needs it to compute the *similarity levels* between individual alumni and the current learner whom the system recommends a new learning path to. We refer to the latter as “target learner”.

There are two ways to obtain such information: (1) each learner fills up a pre-enrolment questionnaire and/or go through a pre-assessment (for both the alumni and the new learner); (2) the system to analyze a learner’s activity log and performances after she has finished the course (for the alumni only). The learner attributes and their grading schemes are:

- *Prior knowledge and skill set* (as specified by e-course designer): Each learner grades her competency on individual knowledge/skill in the scale of 1 (never learnt) to 5 (excellent), and/or go through a pre-assessment (the results will be normalized and rounded up to an integer between 1 and 5);
- *Learning Preference I – Concept-Task spectrum*: Each learner grades her preference, emphasis and competency in learning conceptual or practical knowledge (1 to 5);
- *Learning Preference II – Specialization-Generalization*: Each learner specifies whether she prefers to learn specialized before generalized knowledge (1), or vice versa (5);
- *Learning Preference III – Abstract-Concrete*: Each learner specifies whether she prefers to learn concrete before abstract knowledge (1), or vice versa (5);

- *Learning Preference IV – Free-Guided navigation*: Each learner grades her willingness to comply to the system's recommendations of the subsequent nodes to visit, or to explore the course network at her own will, in the scale of 1 (guided navigation) to 5 (free navigation), with 3 as no preference or "not sure";
- *Analytical skill competency*: Each learner grades her ability in understanding diagrams, flowcharts, etc., in the scale of 1 (poor) to 5 (excellent);
- *Language proficiency*: Each learner grades her proficiency of the language medium used in the e-course, in the scale of 1 (very poor) to 5 (excellent);
- *Similarity of occupations*: Since a learner's occupation might affect her expectation in what knowledge or skill to pick up in the course, and her learning styles, we will work out a semantic diagram that incorporates popular occupations and provides the similarity grade (1 to 5) between each pair of occupation.

The learner attribute set can be expanded to include more factors, e.g., other types of learning preferences, learner's educational qualifications, etc.

On the other hand, the learner's activity log records the learning path that she has visited and the assessment results (performances). To facilitate DYLPAs pheromone computation, the learner's assessment results must be stored in node-by-node basis – see Table 1 for an example.

Table 1: An example of learner's activity log

| Nodes | Performances |
|-------|---------------|
| a | 7 (out of 10) |
| c | 9 |
| e | 6 |
| b | 5 |
| g | 6 |

The example shows that the learning path is $a (\text{performance} = 7) \rightarrow c (9) \rightarrow e (6) \rightarrow b (5) \rightarrow g (6)$.

Overview of the DYLPAs Process

The DYLPAs learning path optimization process is an ongoing process. The entire mechanism can be summarized as the following:

- Recommend a learning path to a new target learner at the early stage of a new course:
 - The human course administrator specifies a "DYLPAs training size" n and a "DYLPAs training threshold" t (see below)
 - Without substantial amount of learner history, DYLPAs recommends but does not reinforce learning paths based on prescriptive rules
 - Past learners' ("alumni") paths and performances are measured and stored
- Recommend a learning path to a new target learner when the number of alumni $> 2n$:
 - Phase I: Pheromone computation (before the target learner starts to study the course)
 - Computes the *similarity levels* between individual alumni and the target learner
 - Selects up to $(n-1)$ alumni whose similarity levels are higher than t
 - Generates ant-like agents corresponding to individual selected alumni to traverse the course network and deposit pheromones according to the alumni's performances
 - Generates an extra ant-like prescriptive agent to traverse the course network according to the learning pathway recommended by the prescriptive rules
 - Phase II: Recommend the next node (after the target learner starts to study the course)
 - Each time when the target learner completes studying one node, the system selects and recommends the next node from all the next possible nodes; the higher the pheromones associated to a "next node", the higher probability that the node will be selected.

The detailed DYLPAs recommendation process is elaborated as below.

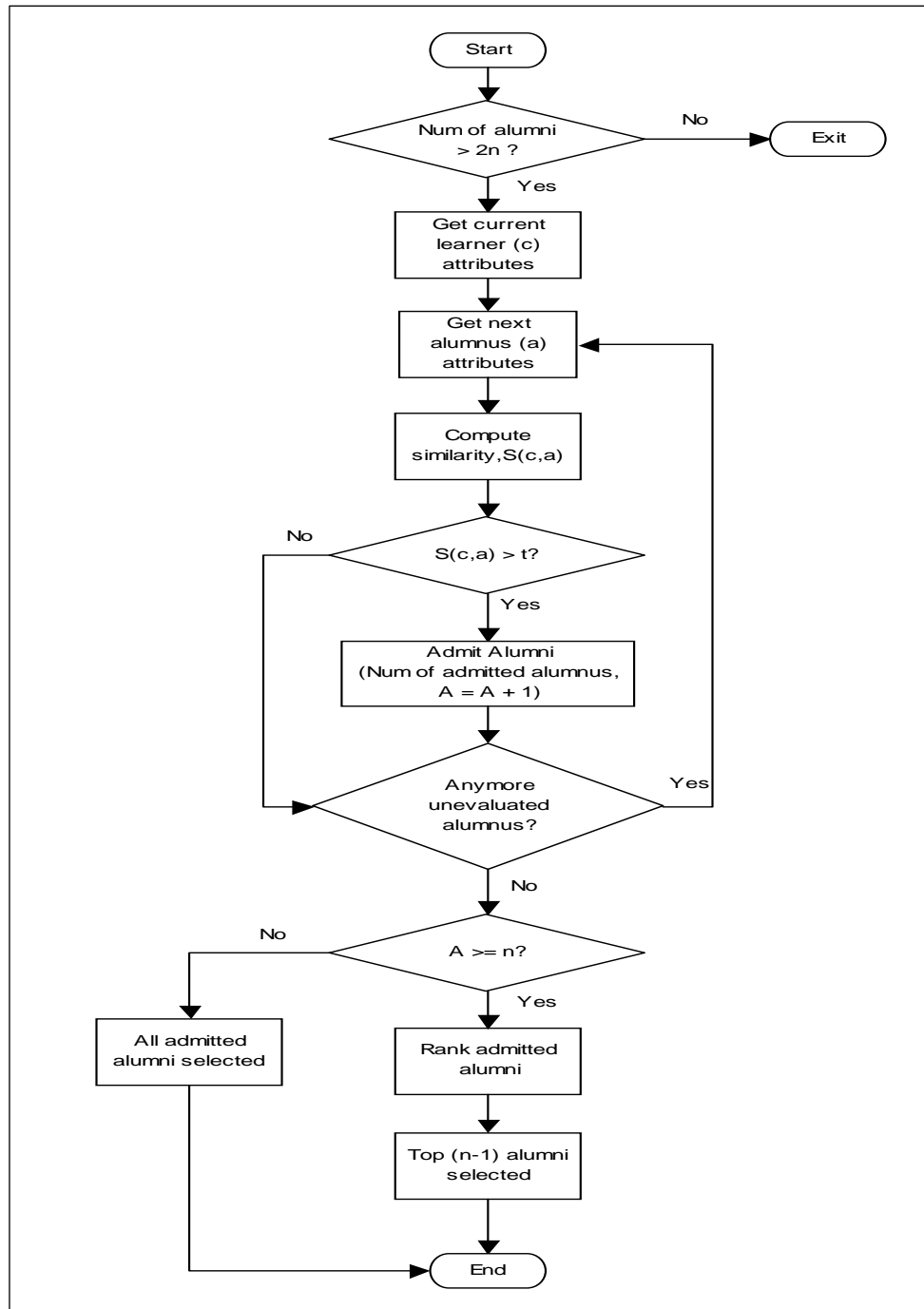


Figure 1: Control diagram of the process of selecting similar alumni

At the Early Stage of an e-Course

When a new course is launched, there is no learner history for DYLPAs to compute the pheromones. Therefore, the system can only recommend a learning path based on built-in prescriptive rules. In principle, our system only recommends the next node after a learner has finished working on the current node, albeit disclosing the complete recommended path in one shot is also fine. However, since it is not mandatory for the learner to comply with the recommendation, the system may need to re-determine the shortest learning path upon her completion of the next node and to subsequently recommend the following node.

So far, the system works in exactly the same way as classic ITS content sequencing techniques. At the same time, learners' learning paths and performances in the course are logged and analyzed.

As time goes by, more and more learners would have “graduated” from the course. The DYLP algorithm may then be triggered, depending on the number of the alumni and the DYLP training size that the course administrator has preset. For example, if the DYLP training size $n = 50$, the administrator may want to trigger the algorithm when the number of alumni surpasses $2n (= 100)$, so that the algorithm would have better chances to identify the subset of alumni who have greater degree of similarity of each new learner.

Selecting Similar Alumni for Training

After the DYLP algorithm has been triggered, the system will first select a set of similar alumni to compute the pheromones. Figure 1 depicts the control diagram of the mechanism.

The DYLP's method of identifying similar alumni is inspired by the work by Tang & Chan (2002), which is a quantification technique to cluster a set of students, i.e., homogeneous student group forming for web-based collaborative learning. The technique has been looking into simplifying them to the set of learner attributes that will be input to the DYLP unit for computing the similarity. However, for performance reason, especially that if there are thousands of alumni are available for comparisons, we adopt a simple grading scheme in the scale of 1 to 5 to quantify each learner attribute. The learner attributes in DYLP have been elaborated in section 4.1 of this paper.

In essence, DYLP computes the similarity level $S(c, a)$ between the target learner (c) and a given alumnus (a) by the normalized weighted Euclidean distance of their corresponding learner attributes,

$$S(c,a) = \begin{cases} 1 & ,D = 0 \\ [\text{Log}(D)]^{-0.5} & ,D > 0 \end{cases}$$

In the formula, x is the quantified value of each learner attribute (each type of prior knowledge or skill is treated as one learner attribute), and w is a weight assigned to each learner attribute, since there should be different degrees of importance for different learner attributes for the comparison. As this is the preliminary version of the DYLP algorithm, we assign *ad-hoc* weights to the learner attributes, that is, $w = 1$ for each prior knowledge and skill type, and $w = 3$ (if the number of the prior knowledge/skill types is ≤ 5) or $w = 5$ (otherwise) for each of the rest of the learner attributes.

$w_i(t_c - t_a)^2$ is where we incorporate the time-decaying feature of pheromones. The time gap between the target learner (t_c) and an alumnus (t_a) in terms of number of months is/was enrolled in the e-course is squared. The *ad-hoc* weight of the attribute is 5.

Note that the formula itself is a variation of the typical formula of TSP ACO, that is, $S(c, a) = [\sum w_x(x_c - x_a)^2 + w_t(t_c - t_a)^2]^{-0.5}$ (where $(t_c - t_a)$ is *inversed* and squared). In our formula, the Euclidean Distance for the time decay is squared (*without* being inversed!) before multiplied by its weight. This is to ensure that both the Euclidean distances of the attributes and time decay have the inversed proportional effects on the degree of the similarity. Next, as the computed values of D is generally high (say, > 100), by applying inverse and square root to the stated values will produce very small similarity values (say, < 0.1). Hence, an even spread of the similarity value between 0 (most similar) and 1 (least similar) could be achieved.

Therefore, instead of TSP ACO and communications network router's ongoing updates of the pheromones in the entire environment throughout the whole course of agent-based simulations where newly computed pheromone of each edge is added to a fraction of the original value (analogous to reinforcement learning), DYLP handles time decaying while selecting the “ant-like agents” (i.e., the alumni).

After that, the alumni will be ranked in the order of individual's similarity with the target learner. Here, we define another parameter – DYLP training threshold t , which is 0.5 or any smaller value if greater similarity is desired.

This serves as a filter for “agent” selection – alumni whose $S < t$ will NOT be selected. The top- $(n-1)$ (n = DYLPAs training size) alumni whose $S \geq t$ will be selected as agents.

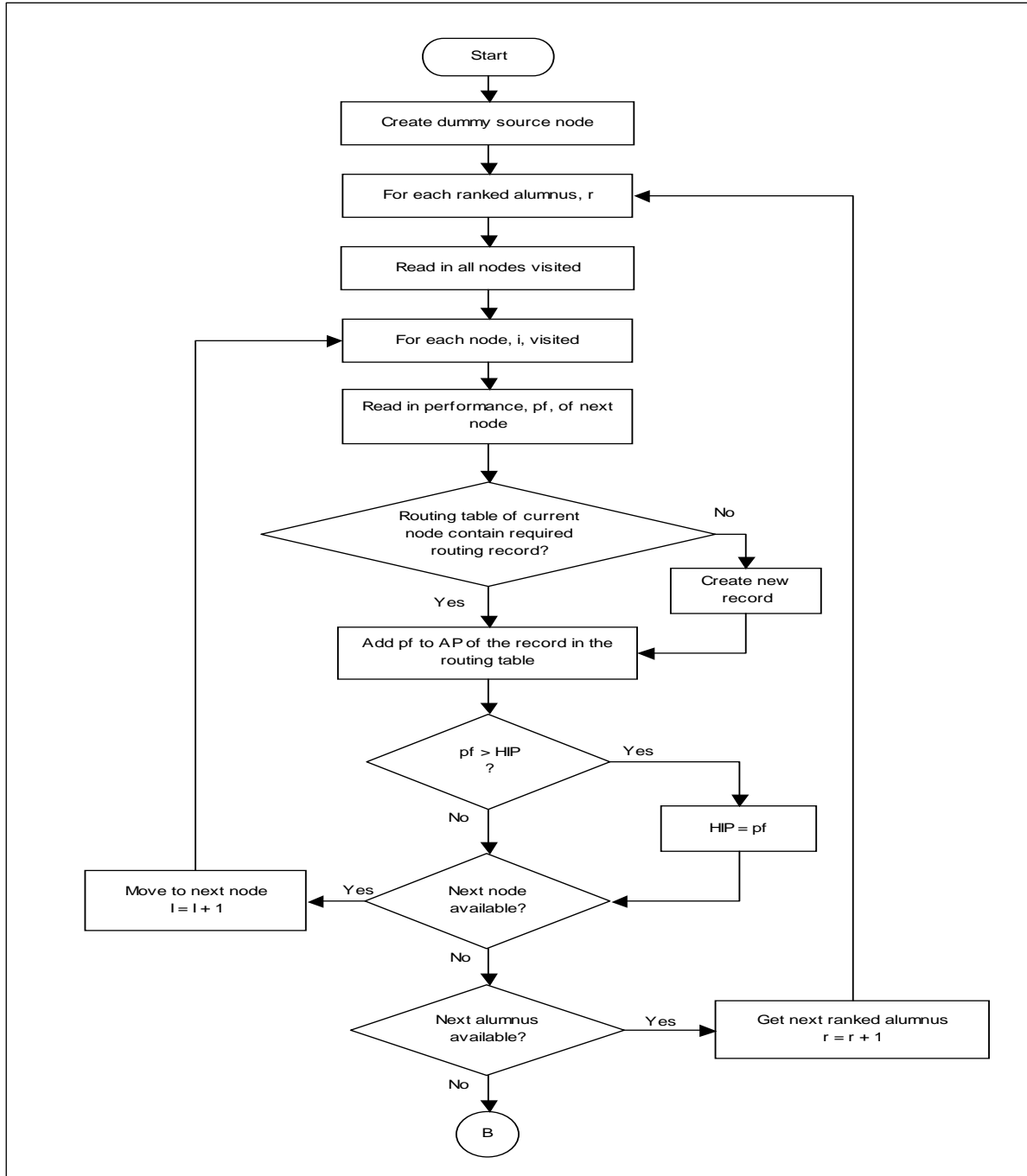


Figure 2a: Control diagram of DYLPAs ant path planning

There is still one last “virtual alumnus” who complies with the “prescriptive path” and this will be treated as the $(n)^{\text{th}}$ agent. We refer to it as “prescriptive agent”. In the case where less than n alumni (say, k number of them) satisfy the condition of $S \geq t$, we will set the weight of the prescriptive agent’s pheromones in the computation as $(n-k)$. In the situation where there are sufficient number of alumni satisfies $S \geq t$, the system will set $k = 1$.

In short, the pathway recommendation mechanism starts with having prescriptive rules dominating the planning process. As time goes by, the amount of alumni that satisfy the condition may also increase, resulting in gradual decrease of the significance (the weight) of the prescriptive rules in DYLPAs planning.

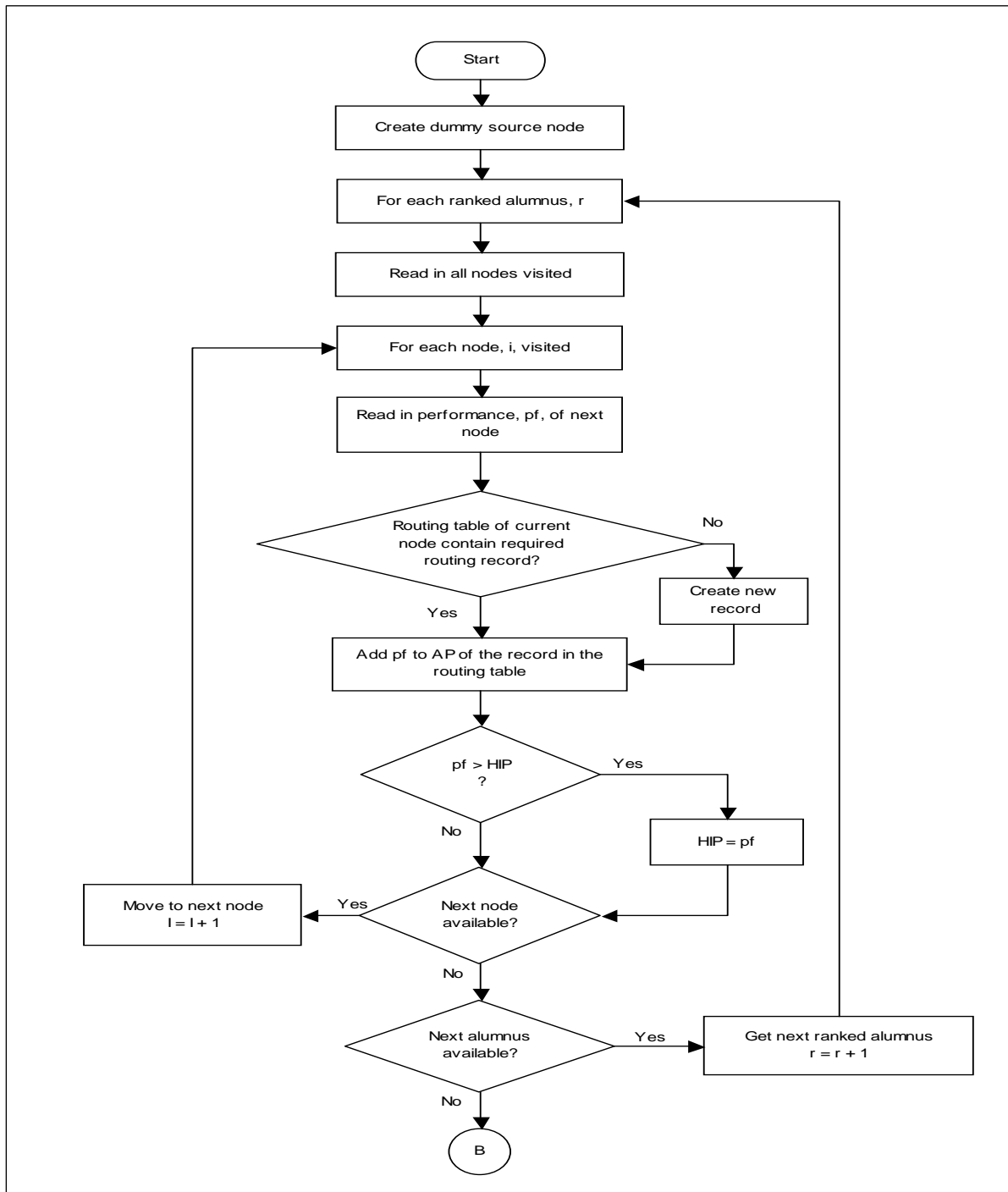


Figure 2b: Control diagram of DYLPAs ant path planning

Computing the Pheromones

Now that the set of agents has been identified, DYLPAs is ready to compute the pheromones. Figure 2a & 2b depict the control diagrams of the pheromone computation process.

Since the learners are given the flexibility to choose whatever next node they want to move to upon the completion of the current node, some “adjacent” pairs of nodes a learner has visited may not have “prescriptive relationship”, e.g., prerequisite, abstract-concrete, etc., at all. There is no problem for DYPLA to handle such cases by assuming that the entire course network is fully connected, i.e., any given node could link to all other nodes in principle, and all arcs are bi-directional.

On the other hand, as stated before, the pheromone stored at a node should reflect the “goodness” of the previous arc in theory. However, when DYPLA makes use of the pheromones to plan the path, a more intuitive way is ACO’s representation of “the probability or ‘goodness’ of traveling from current node i to destination node d via the next node j ”, which should be stored in i instead of j , even though the pheromone is actually a function of the learner’s performance at j .

In essence, each node maintains a “local routing table” as shown in Table 2.

Table 2: Routing table of node i to learning goal node d

| Via (neighboring node) | Accumulated pheromone value (AP) | Highest individual pheromone value (HIP) |
|------------------------|----------------------------------|--|
| J | ... | ... |
| K | ... | ... |
| M | ... | ... |

The routing table is “local” because it only suggests what the “best” next node is, given the goal node of the course. After the learner moves to the next node, it is “none of the (current) node’s business” anymore. On the contrary, conventional routing tables usually store the full path between each source-destination pair of nodes.

Prior to the pheromone computation process, the routing table of each node in the course network is blank. Then, DYPLA computes the pheromones based on selected alumni’s history. For example, an alumnus has chosen node j after finishing i , and her performance measurement in j is pf – how to compute this will be described later. Therefore, the system will check whether the routing table of node i (NOT node j) has stored the pheromone of “to d via j ”. If so, pf will be added to the current pheromone value (that is, the Accumulated Pheromone Value or AP field) of this particular record. If not, a new record of “via j ” will be created and hold the initial pheromone value of pf . The “highest individual pheromone value” (HIP) should store the highest pf value among the alumni who have visited j via i . This field will become useful later. The process continues until the entire alumni log has been read in and processed.

On the other hand, since the first node an alumnus visited has no “previous node”, the system will create a “dummy source node” as the starting point of all the alumni.

After that, the “prescriptive agent’s” path is incorporated into the pheromone computation. Since the path is supposed to be the “best” path in theory, the system “assigns” to the pf value on each node the prescriptive agent has visited by taking the HIP (given the previous node it has visited). However, in case “the prescriptive arc (e.g., from node i to node j)” has no pheromone value (i.e., has never been visited by any alumnus), the system will take the average value of all the HIP values of the other arcs on the same routing table as the pf value of the arc. Finally, each pf value of the prescriptive agent is multiplied by the weight of the prescriptive agent and then added to the AP on the corresponding routing table (or the system will create a new record if necessary). After that, the HIP fields on all the routing tables can be discarded to free the memory space as they are no longer needed.

How are alumni’s performances measured? The performance measurement could consist of one or any combination of, but not restricted to, the following components, subjected to them being generated or made available:

1. Results of the assessments of individual nodes the alumni have visited;
2. Results of the post-assessment of the entire course: we need to split the results of individual questions to their corresponding nodes (However, if an assessment does not cover all the visited nodes, then this component should not be incorporated);
3. Learner’ self-assessment at the individual nodes.

Each component is assigned a weight and all the weighted values will be added together to yield pf .

An alternative way of computing pf is to combine together the assessment result, if applicable, of and time spent on the same node by taking (weight * (result / time_spent)). There is still a weight component here to reflect different levels of significance of the node.

Recommending the Next Node

Figure 3 shows the control diagram of how the DYLPAL algorithm recommends the next node upon a learner's completion of "learning" one node.

The pheromone computation with respect to a target learner has to be completed before she accesses the first node; and the pheromones will "follow" her until she finishes or quits the course. However, if she spends months on the course and other learners have completed the course along the way, the pheromones can be re-computed in the middle of her enrollment to yield better results because of potentially more "similar" alumni. The new pheromones will not affect the "validity" of what the learner has gone through prior to the re-computation due to the local planning nature of the technique.

At the beginning, the DYLPAL System checks the routing table of the dummy source node to recommend the actual first node to the new learner. The relative pheromone value of each entry (i.e., the next node to go) in the table will determine the probability of the corresponding arc being chosen. For example (as in Table 3),

Table 3: Routing table of dummy node to learning goal node d:

| Via (next node) | Accumulated pheromone value (AP) |
|-----------------|----------------------------------|
| <i>J</i> | 13.5 |
| <i>K</i> | 5.1 |
| <i>M</i> | 40.3 |
| <i>N</i> | 2.2 |
| <i>P</i> | 7.6 |

Therefore, the probability of choosing node *m* is $40.3/(13.5+5.1+40.3+2.2+7.6) \approx 0.604$ or 60.4%

In other words, the DYLPAL System constructs a roulette wheel that is weighted by AP values. It then spins the wheel to choose the next node to recommend. The learner will decide whether she will comply with the recommendation or make an alternative choice of her own. After she has completed working on the next node, the process starts all over again to recommend the following node, until the learner reaches the goal node.

There are a few potential variations of the process:

- Not all the "next nodes" in a routing table may "compete" for being recommended. Those with AP value that is below a pre-defined threshold (e.g., smaller than ¼ of the highest AP value) or a cutoff point (e.g., the "next nodes" are ranked in the order of their AP values and those at the bottom half will be discarded, unless there are less than 4 candidates) will not be included to the roulette wheel.
- Instead of constructing a roulette wheel, list all the "next node" options, in the order of their AP values, and displays their probability values to the learner, and let her decide which node to proceed to or even choose a node which is not in the list.
- After the learner has been recommended on the next node to visit (or picked her own node), she can request DYLPAL to pre-compute and display the complete path to the goal node via that particular node by applying the pheromone-based mechanism (or firing the prescriptive rules, if the DYLPAL algorithm has not been triggered yet). This will provide the learner a reference of what she can expect ahead.

Prototype Development and Testing

We have developed a software prototype of the DYLPAL System. It is a web-based software running on Microsoft Windows 2000/XP that is interfaced with a simulated web learning portal. The core pathway planning mechanism is written in C#. The ASP .NET framework is used to develop the web interface so that the prototype is portable to real

e-learning portals that comply with the framework. The simulated web-learning portal contains a Microsoft Access database that stores test data sets, i.e., individual alumni's background and e-learning history. The overall architecture of the prototype is depicted in Figure 4.

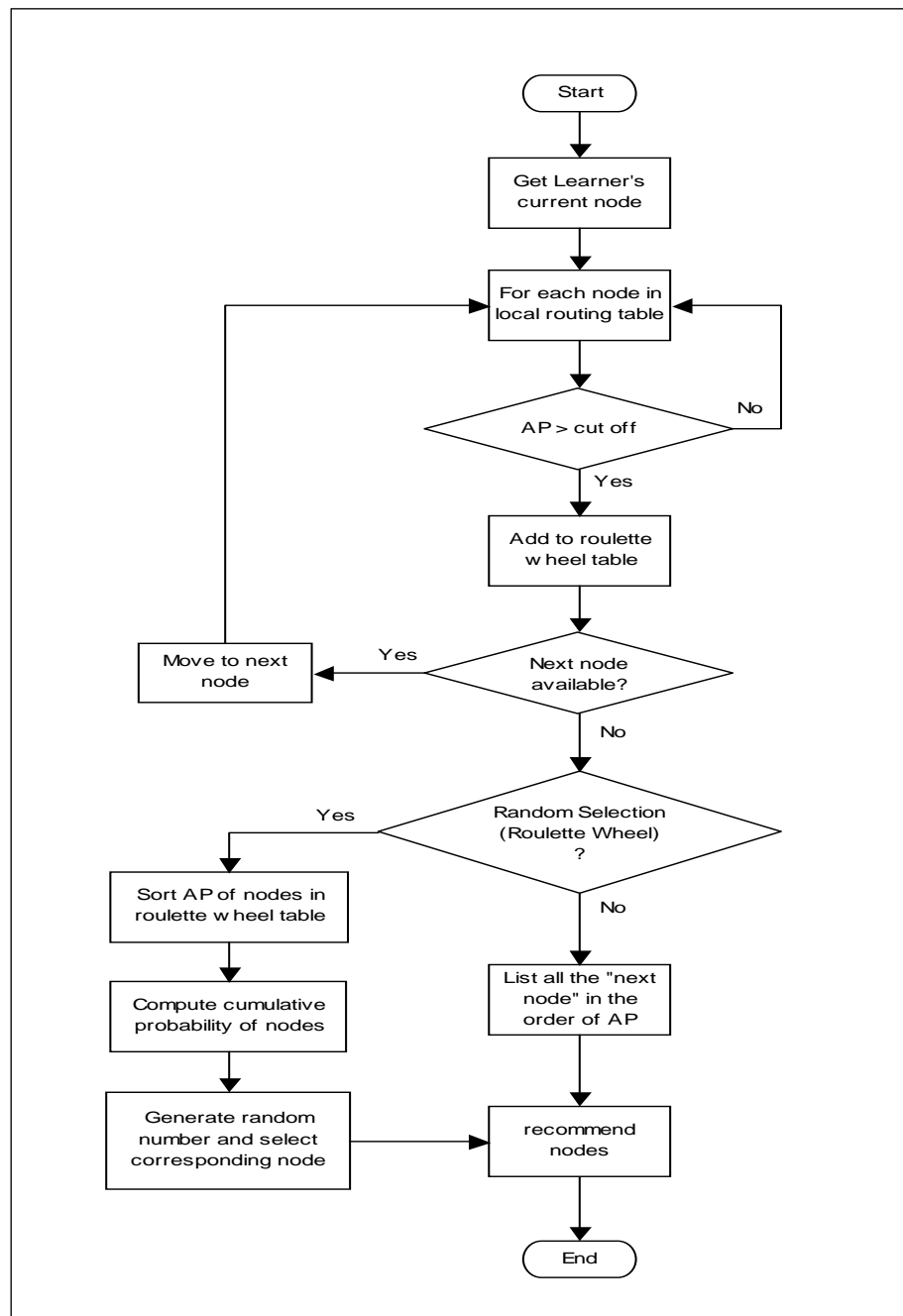


Figure 3: Control diagram of the process of recommending the next nodes

The simulator consists of an inference engine, a controller, an inference engine, a database and an e-learning Portal simulator. Driven by the DYLP algorithm, the inference engine computes pheromones and recommends learning paths. The event-driven controller provides the functionality of data feeding, alumni selection and parameters control (training size, threshold values, etc.). The course data and the learner performance data are fed into the database which will be retrieved by the inference engine for further computations. The controller also acts as a communication hub among the other modules.

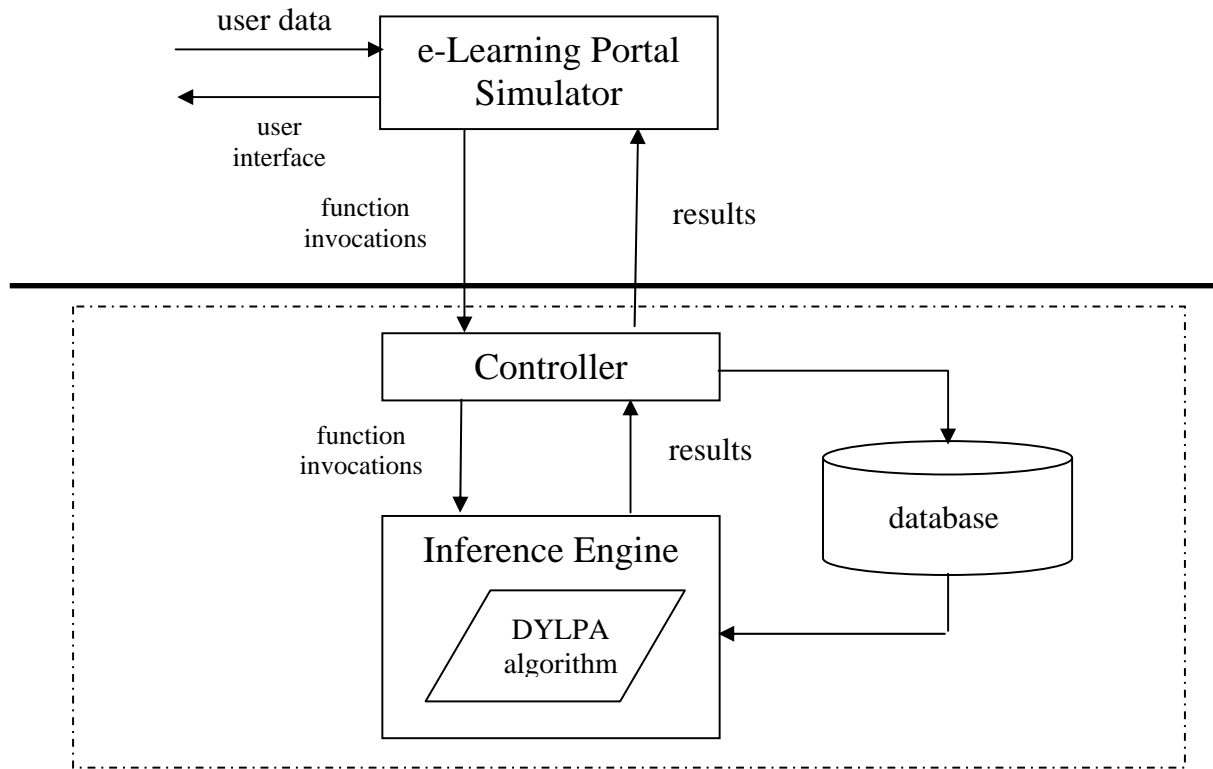


Figure 4: System architecture of DYPLA simulator

The e-learning portal simulator was designed with the purpose of simulating the integration between the e-learning system and the DYPLA. The simulator only feeds the test data into the inference engine, collects new learners' preferences and displays the recommended learning pathway or the next learning node. The test data consists of the course structure and alumni's performance records. It accepts the user input and would be redirected to DYPLA for recommending the best pathway.

Currently, we have validated and verified the prototype with simulated data. There are two different categories of test cases: (1) where number of "similar" (to the target learner) alumni \ll preset DYPLA training size; (2) where number of "similar" alumni $>$ DYPLA training size. As an illustration, consider the following test cases that are subjected to the prescriptive and inductive pathways below,

- Prescriptive Pathway – learning object IDs (nodes): $1 \rightarrow 2 \rightarrow 3 \rightarrow 4 \rightarrow 5 \rightarrow 6 \rightarrow 7 \rightarrow 8 \rightarrow 9 \rightarrow 10 \rightarrow 11 \rightarrow 12$
- Inductive Pathway (what most "similar" simulated alumni went through, inductively, with minor variations among individuals, e.g., some might have skipped node 5 while some others might have visited node 8): $1 \rightarrow 2 \rightarrow 5 \rightarrow 6 \rightarrow 12$

Test Case A (where number of "similar" alumni \ll training size)

- Training Size = 500
- Training threshold = 0.4
- Test Set = 300 "similar" alumni + 200 "random" alumni (whose background and histories are randomly generated – some of which may be "similar" to present student)
- Eventual recommended pathway : $1 \rightarrow 2 \rightarrow 3 \rightarrow 4$

When the DYPLA unit is activated, 303 alumni records were selected while the prescriptive agent carries a weight of $500-303=197$. We would expect that the eventual recommended pathway is the same or similar to the prescriptive path due to the relatively heavy weight of the latter. Instead, the recommended pathway is terminated at node 4

because very few alumni have visited node 4 based on the simulated learner history (as reflected on the inductive pathway).

In real-life, when there is enough training size, such a “broken link” problem is very unlikely to occur. However, as it is a potential issue to DYLPAs, we modified the algorithm by allowing the “routing” to proceed to the next node (in this case, from node 3 to, say, node 5) with much lower AP value as long as the student has yet to reach its learning goal (in this case, it is node 12). After the modification, the recommended pathway becomes:

$1 \rightarrow 2 \rightarrow 3 \rightarrow 5 \rightarrow 6 \rightarrow 7 \rightarrow 9 \rightarrow 10 \rightarrow 11 \rightarrow 12$

where nodes 4 and 8 are skipped due to low visit rates, according to the simulated data. The new recommended path shows the predominant influence of the prescriptive path while the alumni’s historical data still play a small part in varying it.

Test Case B (where number of “similar” alumni > training size)

- Training Size = 300
- Training threshold = 0.02
- Test Set = 300 “similar” alumni + 200 “random” alumni
- Actual recommended pathway: $1 \rightarrow 2 \rightarrow 5 \rightarrow 6 \rightarrow 12 \rightarrow 14$

In this case, with sufficient test set, the result can be predicted accurately as all the selected alumni are having the same background as the user. The random set does not cause obvious effect to the generated pathway because the Alumni Selector will select only the top 300. Therefore, the actual recommended pathway is identical to the “inductive pathway” that we preset for the simulator to generate test data. However, there is still 10% of test set which went through the course network in a random manner. Some simulated alumni have visited some other nodes and yielded “good” results. That explains why node 14 comes into the picture.

In summary, in type (1) cases, the DYLPAs algorithm tends to recommend pathways that tally with the prescriptive pathways as the pheromones deposited by the prescriptive agent carries a greater weight. The greater the number of “similar” alumni increases (type (2) cases), the more the recommended pathways reflect the aggregate choices and performances of the alumni. More details of the validation and verification are reported in Lai, Lee, Chong & Ong (2004).

Related Work

In this section, we compare and contrast four other published similar ACO-based techniques with the DYLPAs mechanism.

Gutiérrez *et al.* (2006) proposed a similar ACO-based approach. In their approach, sequencing graphs record the frequencies and the performances (“successful” or “failed”) of various paths that other learners have been through. The information is presented to the target learner every time she finishes a learning unit (a “node” in our context), so she could choose the next unit by referring to how *all* her peers performed (the numbers of successful and failed peers) in the same situation.

Van den Berg *et al.* (2005) developed a simplified ACO algorithm that only keeps the records of the paths selected by the learners who have “successfully completed the course”, determined by a post-course 5-question multiple-choice quiz, by maintaining a transition matrix that records the number of learner transitions between individual pairs of nodes on such paths. The full path will then be recommended to the next learner with the roulette wheel mechanism. Janssen *et al.* (2007) evaluated the approach by analyzing and comparing the online learning activity logs of more than 800 students who used or did not use this recommendation mechanism. He concluded that the approach were more effective in improving the performances, but were not necessarily more efficient in terms of individual students’ total time spent in studying the online course.

Valigiani *et al.*’s (2005) Paraschool system (see also: Semet, Lutton & Collet, 2003) makes use of another modified ACO algorithm. The system requires the course designers to assign weights to individual arcs within the course network to reflect the “goodness” of the learners following particular outgoing arcs upon completion of a learning

node. The weights will be adjusted by real learners' performances later. Unlike DYLPAs who allow gray-level performance measures for pheromone computation, Paraschool deposits two types of pheromones, namely, "success pheromones" and "failure pheromones", on the arcs for future fitness function-based (a concept borrowed from Genetic Algorithms) computations and recommendations.

Utilizing the ACO technique as well, the Style-based Ant Colony System (SACS) (Wang *et al.*, 2008) categorizes alumni into four learning styles (visual, audio, text or kinesthetic). In recommending the next node, the pheromones deposited by the alumni who fall into the same category with the target learner are favored in the computations. The pheromone computation is not based on alumni's performances but merely the number of times the alumni have traveled.

We argue that the four approaches have different combinations of pitfalls that our DYLPAs algorithm has addressed (see Table 4).

Table 4: Comparison of the features of five ACO-based learning path recommendation mechanisms

| | Pheromone computation based on alumni's paths or performances? | Pheromones are time decaying? | Computation based on whose data? | Combining prescriptive and induction planning? |
|--|---|--------------------------------------|--|---|
| Gutiérrez <i>et al.</i> (2006) | paths | no | All alumni | no |
| Van den Berg <i>et al.</i> (2005) | paths | no | Only alumni who have "successfully" completed the course | no |
| Semet, Lutton & Collet (2003); Valigiani, <i>et al.</i>, (2005) | paths & performances | yes | All alumni | No; but course designers are required to annotate weights on each arc in the course network as "prescribed preferences" |
| Wang, Wang & Huang (2008) | paths | yes | Categorizing alumni according to their learning styles; only alumni who fall into the same category with the target learner are selected | no |
| Wong & Looi (2002) | paths & performances | yes | Computing the similarity level between the attributes of the target learner and individual alumni; only alumni who have high similarity levels with the target learners are selected | Yes |

First of all, all four approaches do not incorporate prescriptive planning as our approach does. With the notion of social navigation in mind, one may argue that a good course sequencing technique could rely solely on past learners' chosen paths and performances in recommending new paths or "the next nodes". The Paraschool system takes one step closer by requiring manual assignment of weights to individual arcs, which become "prescriptive preferences" of the course designers – this is similar to Carchiolo *et al.*'s (2002) system as described in the Literature Review section of this paper. However, we believe that the "classic" prescriptive planning techniques, having been validated by researchers in the past, should still have their place in the recommendation process, particularly during the early stage of a new course when there are very little or no alumni data to facilitate stochastic computations. Our novel approach of combining prescriptive and inductive planning provides a plausible and feasible solution to this issue.

Secondly, in Gutiérrez *et al.*, Paraschool and AACS' approaches, the chosen learning paths and the performances of all the past and/or present learners, regardless of their potentially diversified "learner attributes", are incorporated

into the computation, that is, they treat supposedly heterogeneous “agents” as homogeneous ones. Van den Berg *et al.*’s approach does choose learners for pheromone computations – but only choosing “successful” alumni but ignore other “learner attributes”. Hence, their system computes the same set of alumni data for all new learners who enroll to a course at the same time. SACS simply divide alumni into four categories as their attempt to address the typical ACO techniques’ basic requirement of involving homogeneous agents. Compared to SACS, our approach employs a more fine-grained quantitative method in selecting similar alumni with respect to each new learner.

The time decaying feature of the pheromones is yet another element that the first two approaches lack. We have discussed the rationales behind this feature in section 3, i.e., (a) more “similar” alumni when a growing set of historical data is accumulated; (b) possible updates of the curriculum. Both reasons would make early pheromones gradually becoming less and less accurate for predicting future learners’ performances. Therefore, we argue that time decaying is a significant feature that any stochastic mechanism for social navigation should not ignore, especially for domains that is dynamic and may change over time.

Conclusion

Although inductive course planning is not a new idea in learning technology field, DYLPAs could still be considered novel as it is the first course sequencing technique that explicitly combines prescriptive and inductive planning. Furthermore, given the adaptive capabilities of DYLPAs, this algorithm may be more competitive in stochastic time-varying domains, in which solutions must be adapted online to changing conditions, than in static problems. The online learning domain may be seen as a domain with changing conditions. These changes may be due to curriculum updates, advancement in online instructional and learning tools, changes in the typical profile of the learners, and so on. The ability of the system to adapt to changing conditions is further enhanced by the inclusion of a time-decaying feature that favors more recent alumni than older ones.

As learning technologies are one of the ICT fields that are subjected to the full vicissitudes arising from considering the human factor, our novel technique is naturally bound to face some limitations. For future work, we would like to recommend further investigations on:

1. Weighting the agents

All the ACO-inspired algorithms require homogeneous agents. For DYLPAs, we address the problem of “heterogeneous learners” by selecting the most closely matched alumni with the current learner. All the selected “agents” carry equal weights in pheromone computation. However, since the selected set of agents is not totally “homogeneous”, we recommend further refinement of the algorithm so that the agents could carry different weights that are proportional to their respective similarity levels.

2. Improving the computation of the degree of similarity (including the heuristics)

Our current method of computing the degree of similarity and the choice of learner attributes for the computation are relatively *ad-hoc* and need to be revised. One potential solution is to incorporate other Artificial Intelligence techniques like Genetic Algorithms to learn the weight of the learner attribute settings. Another possibility is to adopt relevant techniques developed for other e-learning systems, e.g., the algorithm developed by Wang, Tsai, Lee & Chiu (2007).

3. Time-decaying factor

DYLPAs incorporate the time-decaying factor of pheromones indirectly by considering it as one of the learner attributes that is taken into account in determining the degree of similarity. The current version proposes the difference of the time both learners are enrolled in the e-course. We propose the exploration of alternative ways of measurement, e.g., the degree of changes of the curriculum between the points when both learners are/were enrolled.

4. More elegant handling of backward learning

We have introduced a quick fix to handle the potential backward learning behaviors of the learners. Further investigation on the nature of such behaviors (especially that there may be other personal factors or reasons behind this) may shed light on whether our present fix is valid and if not, and whether the algorithm could be refined to handle such situations properly.

Finally, we need to validate the algorithm itself by testing it on real e-learning system with real alumni history and real e-learners as users.

In the long run, however, we believe such an inductive mechanism, guided by the past learners' aggregate performances, has the potential to become a formal validation technique of all prescriptive course sequencing and delivery planning techniques, which is similar to a technique that utilizes ACO for auditing of pedagogical planning as proposed by Guitérrez, Valigiani, Jamont, Collet, & Kloos (2007), or even for discovery of new prescriptive rules.

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How are universities involved in blended instruction?

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ABSTRACT

The purposes of this study are to examine faculty involvement in blended instruction and their attitudes towards the instructional method. The study also explored how universities support faculty in their current practices on blended instruction and the challenges in supporting faculty. The target population of this study was Institute of Higher Education (IHE) coordinators and faculty members of 151 extensive doctoral research universities classified by the Carnegie Foundations. Two online survey instruments, one for the coordinators and the other for faculty were administered to the target population. Of the 151 targeted population, 34 IHE representatives and 133 faculty members from 33 universities responded to the survey questionnaires. The study found that the most commonly selected blended method (64.4%) was face-to-face instruction with supplementary online instructional materials. In addition, faculty (95.9%) actively participated in designing, developing, and/ or maintaining their instructional materials. Most had positive attitudes towards blended instruction as they believed it played a role in improving the quality of their instruction. In addition, participating universities reported providing faculty with the necessary help such as an online help desk, workshops, instructional designers, and technology specialists in support of goals to increase the number of online or blended instruction. However, faculty workload (70.6%) and lack of faculty motivation and enthusiasm (61.8%) were the biggest challenges in pursuing the institutional goals. Based on the findings, suggestions are made to promote blended instruction.

Keywords

Blended instruction, online instruction, Classroom instruction, Face-to-face instruction, Faculty involvement, Faculty motivation, University support, hybrid instruction

Introduction

Blended instruction is an instructional approach that combines the benefits of online and classroom instruction. It initially originated from efforts to improve distance learning environments. In particular, it was aimed at improving online learning environments where learners can be easily disoriented due to a lack of communication or direct guidance (Marsh II et al., 2004; Rossett, et al., 2003). Regarding the learning environment, Savery and Duffy (1995) argued that there are two factors that affect learners' attitudes toward learning. One is the familiarity with the instructional medium and the other is the ability to make something meaningful out of the material presented. According to Savery and Duffy (1995), when comparable content is presented to learners, both on-screen and in printed text, the information presented on screen is mentally more demanding than the printed text. Learners find it difficult to make connections between information presented and its value due to the unfamiliarity of the presentation mode.

Marsh II et al., (2004) suggested that basic strategies for improving student learning are to put greater responsibility on students and to improve the presentation method by utilizing tools such as technology. Consequently, in online instruction, there have been many attempts to improve the presentation mode by employing advanced technology tools or adding classroom meetings to online instruction. Students in higher education tend to be less satisfied with totally online courses when compared to traditional classes (Sikora & Carroll, 2002). Therefore, based on many studies (Colis and Moonen, 2001; Deilialiouglu & Yildirim, 2007; Donghohue, 2006; Murphy, 2002, 2003; Schmidt & Werner, 2007; Valiathan, 2002; Young & Ku, 2008), researchers have concluded that a mixture of face to face and online instructional formats is the best solution for instructional problems and needs, accelerating the students' learning process.

However, there are still issues related to delivering blended courses with online components. These become challenges for faculty, institutions, and instruction. In particular, issues such as instructional support, faculty motivation and enthusiasm, and technology problems have been raised as problems in developing online instruction in many institutions since online instructional strategies have been available. Barr & Tag (1995). Many authors (Barr

& Tag, 1995; Johnson, 2002) have claimed that university policies should be revised for faculty who are motivated to pursue newer instructional formats; promotion policies such as tenure should be revised based on faculty workloads and levels of engagement in extra instructional activities.

Another critical issue in blended instruction is a lack of evaluation procedures (Rovai, 2003). The process of identifying the degree to which the learning objectives are achieved is the basis for assessment of students and for course evaluation. Since evaluation is a process of reflection and revision, it is important for instructors in planning further instruction. However, few researchers have found appropriate evaluation frameworks and procedures for blended instruction in academic settings. Therefore, this study focuses on exploring faculty involvement and institutional support in delivering blended instruction and challenges and issues related to the topic.

There are many definitions possible for blended instruction. Among the definitions, the definition used for this study blended instruction is a combination of classroom and online instructional methods regardless the proportion of the instructional formats. There have been many studies conducted related to faculty attitudes, motivations, and institutional support in delivering online instruction or blended instruction. However, studies on faculty involvement in developing online instructional materials are scarce. In that aspect, this study is significant to explore how practically faculty are involved in blended instruction and how universities support their faculty in pursuing innovative instructional delivery method.

Following research questions are formulated to examine these issues in detail:

- a) In what ways are faculty involved in delivering blended instruction?
- b) What are the faculty attitudes toward and perceptions of blended instruction?
- c) How do institutions support faculty involved in blended instruction?
- d) What kinds of challenges do institutions have in supporting faculty in delivering blended instruction?

Literature review

Definitions of blended instruction

Blended instruction is defined in many different ways according to the instructional methods and architectures. Valiathan (2002) defines blended instruction as a combination of different instructional systems, such as collaboration software, Web-based courses, EPSS, and knowledge management practices, as well as various event-based activities. Minocha (2005) defines blended instruction as a mixture of various instructional events and activities, such as information, interaction, simulation, games, collaborative learning, and classroom-based learning. In the same context, Mitchell and Honore (2007) define blended instruction as “learning involving multiple methods and approaches, commonly a mixture of classroom and e-learning.” According to Graham (2006), even though there are huge variations in defining blended instruction, the three most commonly mentioned definitions are (1) combining instructional modalities (or delivery media) (Bersin & Associates, 2003; Orey, 2002a, 2002b; Singh & Reed, 2001; Thomson, 2002), (2) combining instructional methods (Driscoll, 2002; House, 2002; Rossett, 2002), and (3) combining online and offline instruction (Reay, 2001; Rooney, 2003; Sands, 2002; Ward & LaBranche, 2003; Young, 2002).

According to Sing & Reeds (2001), blended instruction is an instructional delivery method where more than one delivery mode is adopted for optimizing learning outcomes. In this concept, different instructional strategies and medium are integrated into learning needs. The examples of instructional attributes are (a) offline and online learning; (b) self-paced and live-collaborative learning; (c) structured and unstructured learning; (d) work and learning; and (e) synchronous online formats and self-paced asynchronous formats.

Delialiouglu and Yildirim (2007) view blended instruction as a combination of classroom instruction and online instruction in which instructors can pursue their pedagogical goals by mixing benefits of two instructional modalities. In the same context, Marsh II et al., (2004) and Rossett et al., (2003) claim that blended instruction usually describes a combination of face-to-face and online instruction in which major components of the instruction are delivered online with the remainder being face-to-face instruction. Blended instruction includes both online and classroom instructional components, yet it is considered a format for online instruction (Rossett et al., 2003). In this case, a small portion of classroom instructional components are then employed in order to fill in the gaps in online instruction.

However, in practice, it is commonly found that online instructional components are merged with offline instruction as an integral part of offline instruction. Thus, within the defined combination of offline and online instruction, many different approaches are found in the use of instructional proportion, technology tools, and instructional strategies. For instance, The Office of Educational Technology of the University of California in Los Angeles (Office of Ed Tech) defines blended instruction as a way to “offer curriculum through a combination of face-to-face and electronic mediums.” Within this definition, technologies, especially online instructional components are used to replace a significant portion of classroom instruction. This approach works well in a large classroom; since it is difficult for an instructor to accommodate diverse students’ needs in large classrooms, a strategic instructional method such as blended method is necessary (Blended Instruction Case Studies, 2005).

On the other hand, Burgon and Williams (2003) approached a blended instruction from a totally different perspective in which offline classroom lectures and online instructional materials were combined for both on and off campus students. The blended course was an undergraduate religion course with 49 on-campus students and seven distance learners. The 49 on-campus students were taught in a traditional classroom environment with lectures. The distance learners took the course asynchronously online. The class met twice a week, and traditional lecture was used as an instructional method for classroom instruction. Course materials were uploaded online for the distance learners, and both in class students and distance learners had access materials such as course syllabus, class notes, assignments, and reading. Online discussion forums were required for both on and off campus learners to share ideas, questions, comments, and experiences.

The article claimed that, in this format, distance learners could have felt as if they were in a classroom environment while they were interacting with students in the classroom rather than only talking with off-campus students. Furthermore, classroom students could enjoy talking with distance learners since the distance learners brought their various experiences to online discussion forums. The classroom students could also use online class notes for reviewing the concepts that they could not understand in class. In addition, the distance learners could experience a “more intangible aspect of the institution embedded in the cultural transmission of synchronous on-site courses” (Waddops & Howell, 2002) through discussions with in class students. The authors claim that this type of blended course benefits both in class and distance learners.

Models of blended instruction

Table 1. Options of blended instruction

| Blended Instruction | | | | | |
|--|------------|---------------------------|-----------------------|---------------|----------------|
| (Courses in which a portion of online instruction is replaced by classroom activities) | | | | | |
| Online instruction | | | Classroom instruction | | |
| Environment | Activities | Applications | Environment | Activities | Applications |
| Computer-based online learning | Lecture | Course Management | Classroom | Lecture | Vary from |
| | Practice | Tools (CMT) | Synchronous | Presentations | class to class |
| Synchronous | Self-study | Video | Two-way | Group-work | |
| | Discussion | Audio | communication | Tutoring | |
| Asynchronous | Assignment | Presentation Tools | | Assessment | |
| One-way communication | Group work | (PowerPoint, Flash, etc.) | | | |
| Two-way communication | Simulation | | | | |
| | Assessment | Communication tools | | | |

As repeatedly mentioned above, blended instruction is described in many different ways, yet online and offline instruction are the two major instructional delivery modes. Instructional components in each mode depend on characteristics of courses and instructors’ capability, knowledge, and decisions in designing instruction with the technology tools and media that are available to use on campus. Table 1 above depicts common instructional components in blended instruction based on reports from several universities such as Harvard University, the University of California system, University of Central Florida, University of Northern Texas and others.

Rossett et al., (2003) claimed that for successful blending, instructional tools and design strategies are important components, and all the components within the instructional method should be appropriately integrated. Usually, in a

blended model, there have been specific instructional elements as listed in Table 1. However, options for blending are wide open to instructors, not just limited to the activities and applications that have been known or used in the past. Instruction can be composed of a combination of formal and informal approaches, technology- and people-based activities, independent and convivial activities, or directive- and discovery-oriented items. The right blend depends on instructional conditions and instructors' own judgment and decisions in applying their instructional strategies for their instructional needs (Rossett et al., 2003).

On the other hand, Wenger & Ferguson (2003) explain a blended learning model in a task-oriented manner with four components [teaching, coaching, studying, and practicing]. Teaching refers to online content delivery to learners. Coaching refers to instructor-guided learning in both online and offline environments. Practice refers to authentic learning through hands-on experience using simulations or virtual learning activities. Studying refers to learners' efforts to achieve desired learning goals using resources such as online self-study tools, instructor's help, and any other kinds of resources available. Detailed instructional components of this model are listed as *Figure 1* below.

| Studying | Learner Self-Navigation | | Practicing |
|----------|-------------------------|--------------------|-------------------------------|
| | | | |
| | Books, articles, guides | Authentic tasks | Experience and practice Focus |
| | References | Role play | |
| | Whitepapers | Projects | |
| | Asynchronous contents | Case studies | |
| | Job aids | Peer discussion | |
| | Glossaries | Discussion forums | |
| | FAQs | | |
| | Classroom lectures | Exercise | |
| | Synchronous contents | Diagnostic labs | |
| | Demonstrations | Practice labs | |
| Teaching | Reviews/discussions | Mentoring/tutoring | Coaching |
| | Video | Experiments | |
| | Videoconferencing | | |
| | Guided Navigation | | |

Figure 1. Specific learning elements of blended model (Wenger & Ferguson, 2003)

While many models (Rossett et al., 2003; Wenger & Ferguson, 2003) deal with instructional modalities and learning tasks, Valiathan(2002) focuses on learning goals where the blended model is categorized in three ways: (a) skill-driven; (b) attitude-driven; and (c) competency-driven. In a skill- driven approach, a combination of self-paced learning modules and classroom instruction support student learning of knowledge and skills through a step-by-step learning process. In this approach, learners are expected to complete learning materials such as books and papers along with asynchronous self-paced online learning modules. Instructors support learners using online communication systems such as email discussion forums, and instructor-led contact sessions.

In addition, instructors may demonstrate procedures or processes of skills and knowledge to be achieved in synchronous web-based classes or scheduled-classroom instruction based on their students' needs. The synchronous sessions provide opportunities for students to learn how to apply their skills and concepts obtained in class. The techniques needed in this approach involve instructors who have to align appropriate time and topics in both asynchronous and synchronous instruction with the characteristics of learners.

The attitude-driven approach is described as an instructional approach that blends various collaborative learning events in an effort to develop specific behaviors and attitudes in learners. In an attitude driven approach, since both classroom instruction and technology-based collaborative learning events are scheduled, it is useful for teaching content that requires peer-to-peer interaction. Higher order thinking, negotiation, and critical reflection skills can be developed through group work and discussions with peers using technology-enhanced communication tools.

The competency-driven approach is an instructional approach that is designed to teach tactical knowledge. In this approach, various media are applied to learning events in an effort to guide students in learning facts, principles, and skills that are required in the process of making decisions. Table 2 describes each approach briefly.

Table 2. Blended Instructional Approaches

| | Skill-driven approach | Attitude-driven Approach | Competency-driven Approach |
|--------------------------|-------------------------|--|----------------------------|
| Methods | Online learning modules | Collaborative learning | Mixture of media |
| Targets skills/knowledge | Skills and knowledge | Higher order thinking, Critical thinking | Tactic knowledge |

As describe above, there are huge variations in defining blended instructional practices and there is no accepted standards for formulating blended instruction. Different institutions implement it in different ways (Delialiloglu, & Yildirim, 2007).

Related studies

Faculty involvement in blended instruction

For classroom instruction, instructors are involved in the organization, delivery, and assessment of the course contents. However, when online instructional materials are added, instructors have to work as an instructional designer, technology specialist, and administrative advisor at the same time (Restauri, 2007). In the case of MIT, the university require faculty to produce their own course website using the school Learning Management System (LMS) as a part of ordinary instruction. Faculty feel that producing course materials is an unacceptable burden for them (Abelson, 2008).

Therefore, in many cases, faculty collaboratively work for developing course materials and course websites. For example, Haixia and Morris(2007) illustrate a successful example that faculty members who teach humanities worked as a team to develop blended instruction. In this case, four faculty members played a role as an instructional designer and technologists to design and develop the instruction. The faculty members worked together to decide a level of the lesson, develop content, select textbooks, review contents and resources, and develop student assessment tools. After delivering the course, the faculty expressed that they were satisfied with their job as a course designer as well as a developer since they could produce creative course materials. They also mentioned that if they had stronger technical skills, they would have been more creative and innovative in the process of designing instruction.

Ellis et al., (2006) and Gerber et al., (2008) claim that the blending of pedagogy and technology changes the nature of teaching and learning by providing a means of access to digital resources and interactive communication tools. Gerber et al., (2008) indicates that students can better understand the key concepts and construct their own knowledge when classroom lectures are combined with online discussion activities. In the same context, blended instruction is beneficial to students because it takes both instructivist and constructivist approaches in its design and the process (Delialoglu & Yildirim ; 2007). In a blended learning environment, students are not easily disoriented than purely online learning.

In the case of University of Central Florida (Dziuban and Moskal, 2001), a typical three hour classroom instruction was replaced with a two hour online instruction session. This change was successful for both the university and students, financially and practically. The university was able to operate multiple classes in one classroom more efficiently, using the existing infrastructure of the university. Since an instructor could handle a large class with the combination of class and online instruction, it was cost efficient for the university as well. Students were able to be engaged in the course more actively through online activities, while in a large class it is difficult to make any personal contact with professors during and after the class. As a result, it was reported that students' withdrawal rates were reduced, and the students enjoyed the course more when compared to traditional classes.

As mentioned above, a combination of two instructional delivery methods provides great advantages for students, instructors, and institutions (Correll and Robison , 2003; Dziuban & Moskal, 2001; Ellis et al., 2006; Dalsgaard & Mikkell, 2007, Delialoglu & Yildirim, 2007; Gerber et al., 2008). For students, blended instruction provides active learning environment and flexibility in using time and resources. For faculty, the instructional method provides more time to spend with students individually and in smaller groups and improved quality of interaction with students. For

the institution, the blended approach increases flexibility in scheduling courses and improves the usage of limited resources such as classrooms and parking space.

Challenges and issues related to blended instruction

On the other hand, there are also many studies focusing on obstacles and challenges for adapting blended instruction. Usually, faculty attitudes toward the use of technology use is addressed as one of the biggest challenges along with other things such as faculty workload, and a lack of release time and support by the university (Tabata & Johnsrud, 2008). The use of technology requires changes in the mindset of pedagogy. However, studies report that there are still many faculty members who have pedagogical difficulties in adapting new instructional delivery method because they value the traditional way of knowledge sharing (Hollis & Madill, 2006). Since they are not certain about the value of technology, and their roles and abilities in the process of teaching (Kim & Baylor, 2008), they worry that delivering instruction online would decrease the quality of the instruction and students might feel hard to achieve their educational goals. Some faculty members even perceive that online instruction threatens their academic freedom by designating the way of teaching. Chai and Lee (2008) argue that when instructors do not believe that technology does not fulfill their needs, they are not likely to adjust their instructional strategies to optimize the learning outcomes. Faculty attitudes towards the course influence quality of instruction (Deubel, 2003). As the primary key ensuring the quality of instruction, changes in the mindsets such as pedagogical assumptions, values, beliefs, and attitudes play a fundamental role. Therefore, it is important for faculty to accept the value of innovative ideas and tools (Kim et al., 2007; Papanasasiou & Angeli, 2008).

Faculty workload and instructional support are often discusses as problems as well (Crumacker, 2003). According to Tsai et al., (2008) & Lewis & Abdul-Hamid (2006), faculty who use course specific websites have to work more compared to those who do not use them. When online instruction is involved, instructors usually have to put more time and energy for the course, dealing with various instructional and technical problems. In many cases, even though faculty are interested in technology or new delivery medium, they tend to be reluctant to participate due to the commitment of time needed to produce course content and to deliver course materials(Tabata & Johnsrud, 2008).

It is clear that designing and developing blended courses requires greater amounts of time than designing classroom instruction. In particular, blended courses should be more elaborately designed than online or classroom instruction only by balancing the portion of each delivery method. For doing that, faculty need to understand the nature of the delivery format and the medium, and have the necessary skills and knowledge (Garrison & Kanuka, 2004; Lewis & Abdul-Hamid, 2006; Young & Ku, 2008). In many cases, faculty do not have expertise in the use of technology and they have to spend quite amount of time to obtain knowledge and skills necessary to design and operate the instructional materials and systems. During the semester, it is hard for faculty to have released time as well since they have to attend the class while updating their online instructional materials at the same time.

However, universities do not have adequate support for professional teaching practices (Donoghue, 2006; Restauri, 2007). Nowadays, universities give pressure to faculty to use technology in their courses. Yet, there are not many universities that provide full support for delivering blended instruction. Some universities even expect faculty to teach themselves on necessary technical skills (Restauri, 2007). In addition, few universities provide faculty with incentives or promotions for attempting new instructional method (Tabana & Johnsrud, 2008; Wagner et al., 2008). Typically, universities evaluate faculty's professional development by their research abilities and service efforts for the community. Time spent in developing blended learning courses is not counted as time spent on their professional development. This issue is particularly important for faculty at research universities who face high expectations in research and publications (Howell et al., 2004).

Another critical issue is instructional support regarding the evaluation of blended courses. According to Oh and Lim (2005), the evaluation process that is currently being used for university courses focuses on either online or classroom instruction. In many cases, instructors use course evaluation instruments that are designed for distance education as an alternative choice for evaluating blended instruction. The evaluation criteria in these instruments often do not take into account particular aspects of the blended instructional method. The lack of an appropriate course evaluation method raises issues regarding different evaluation needs for blended instruction. Given the fact that blended instruction is widely used in many institutions, a standardized evaluation framework for blended instruction is necessary in those settings.

Research method

Participants

The respondents consisted of two groups; faculty group and the institutions for higher education (IHE) representatives' group. The faculty group consisted of 133 faculty members from 30 randomly selected universities out of the 151 universities that were classified as extensive doctoral universities by the Carnegie foundations. The IHE representatives' group consisted of 33 staff of the Center for Teaching and Learning from the 151 universities. The 151 targeted universities included 109 public universities and 42 private universities.

Instruments

Two types of questionnaires were developed by the investigator, one for faculty and the other for the IHE representatives. The questionnaire for faculty (survey A) consisted of fourteen (14) questions and the questionnaire for the IHE representatives (survey B) consisted of nine (9) questions. The two questionnaires contained both multiple choice questions and 6 Likert scale questions. A comment box was given for each multiple choice question so that the respondents could provide their additional information if there was any. Detailed information about the survey instruments is shown in Table 3.

Table 3. Survey instruments

| Category | | Type |
|----------|---|-----------------|
| Survey A | Instructional delivery formats that faculty use | Multiple choice |
| | Faculty participation in developing online course materials | Multiple choice |
| | Faculty skills in developing online course materials | 6 Likert scale |
| | Faculty attitude towards blended instruction | 6 Likert scale |
| Survey B | Institutional support | 6 Likert scale |
| | Institutional goals | Multiple choice |
| | Assessment methods | Multiple choice |

Four experienced researchers in the field of instructional technology examined the survey instruments to confirm the validity of the questions and the pilot test was conducted with like respondents to confirm the reliability and validity of the instruments. According to the pilot test, the reliability of the survey showed 0.86 for survey A and 0.83 for survey B.

Data collection procedures

The participating departments were randomly selected by the investigator using the random number selecting process in Excel and the email addresses of faculty members and staff were obtained from the participating universities' websites. An email message describing the purposes and procedures of study, and the request for participation were created and sent to the potential participants. The survey instruments and informed consent form were developed by the investigators and uploaded on the investigators' personal Website. All the participants in the selected universities were invited to participate in the study, but it was clear that participation was voluntary and that participants could withdraw their participation at any time. Reminder messages were sent to the faculty who had not responded to the questionnaire one week later the initial contact, and second reminders were sent one week later the first reminder. The completed survey was also submitted to the investigator's email account when the participants completed and clicked the "submit" button placed at the bottom of the survey.

Analysis of Data

Responses to the questions were entered into SPSS, and the data were summarized descriptively using frequency tables and figures. In addition, Chi-square test, LSD-test, and Turkey-test were used to compare the data by variables such as gender, institutional type, and participants' teaching experience.

Findings

Demographic Information

Total 133 faculty members participated in the study. Of the total 133 faculty respondents, 68 respondents (50.8%) were male and 65 respondents (49.2%) were female. When analyzing the data by age, seven (7) respondents (5.3%) were younger than 30 years old, 10 respondents (6.8%) were between the ages of 31-40, 19 respondents (14.4%) were between the ages of 41-50, 32 respondents (24.2%) were older than 51 years old. Table 4 provides participant data by their gender and age.

Table 4. Faculty information by gender and age

| Age | Gender | | | | | |
|------------|-----------|---------|-----------|---------|-----------|---------|
| | Male | | Female | | Total | |
| | Frequency | Percent | Frequency | Percent | Frequency | Percent |
| 30 or less | 7 | 5.3% | 4 | 3.0% | 11 | 8.3% |
| 31-40 | 10 | 6.8% | 13 | 9.8% | 22 | 16.7% |
| 41-50 | 19 | 14.4% | 23 | 17.4% | 42 | 31.8% |
| 51 or more | 32 | 24.2% | 25 | 18.9% | 57 | 43.2% |
| Total | 68 | 50.8% | 65 | 49.2% | 132 | 100.0% |

In the case of the IHE representative group, 34 IHE representatives returned the survey instruments. Representatives of 28 public universities (28 of 109) and five private universities (11%) returned survey questionnaires. The overall response rate was 22%, and the response rate of public universities was more than two (2) times higher than the case of private universities. Respondents in the IHE representatives group varied in titles, roles, and responsibilities in their respective universities, and in the focus of their activities. Categorizing the respondents by position, there were 18(52.9%) directors/coordinators, three (8.8%) assistant directors, and 13(38.2%) instructional specialists/media specialists.

Table 5. The IHE representatives by position and university type

| Position | University Type | | | | | |
|---|-----------------|---------|-----------|---------|-----------|---------|
| | Public | | Private | | Total | |
| | Frequency | Percent | Frequency | Percent | Frequency | Percent |
| Director, Coordinator | 17 | 51.45% | 1 | 2.85% | 18 | 54.3% |
| Assistant director | 2 | 5.75% | 1 | 2.85% | 3 | 8.6% |
| Instructional specialist/ Media specialist | 9 | 25.7% | 4 | 11.4% | 13 | 37.1% |
| Total | 28 | 82.9% | 6 | 17.1% | 34 | 100% |

In what ways are faculty involved in blended instruction?

In order to examine the ways of being involved in blended instruction, responses to the questions about the instructional formats, faculty involvement in developing online instructional components, and technology skills were analyzed.

When analyzing the responses about the instructional format that faculty deliver, 127 faculty of the total 133 participants responded the question. The most commonly selected instructional delivery formats used by faculty was face-to-face instruction with supplementary online instructional components (64.4%). The second most commonly selected method was blended instruction in which less than 50% of the instruction is delivered online with remainder being face-to-face instruction (19.7%). Blended instruction in which more than 50% of the instruction is delivered online with the remainder being face-to-face instruction (12.1%) was ranked third. As a result, the most common instructional delivery format that faculty has taken was offline instruction with supplementary online instructional components. Table 6 depicts the information about the delivery method in detail.

Table 6. Instructional delivery formats (n=127)

| Item | Frequency | Percent |
|--|-----------|---------|
| 1. Face-to-face instruction with supplementary online instructional Components | 85 | 64.4% |
| 2. Blended instruction in which less than 50 % of the instruction is delivered online with remainder being face-to-face instruction | 26 | 19.7% |
| 3. Blended instruction in which more than 50 % of the instruction is delivered online with the remainder being face-face instruction | 16 | 12.1% |
| Total | 127 | 84.1% |

When analyzing the responses to the question about faculty involvement in developing online instructional components, 122 faculty responded to question. Of the 122 respondents, 117 respondents (95.9%) reported participation in at least one of the five(5) course development activities (see Table 7) while five(5) respondents (4.1%) answered that they did not participate in any of the activities at all. Of the 117 respondents, 96 respondents (78.7%) were involved in designing course content, 98 respondents (80.3%) were involved in organizing instructional materials, and 94 respondents (77%) were involved in developing course materials (77%). A small number of respondents were involved in maintaining a developed course website (55.3%), and fewer than half (45.9%) were engaged in designing a course website.

Table 7. Faculty Participation in Online Course Development Activities(N=122)

| Item | Frequency | Percent |
|--|-----------|---------|
| (a) Designing course content | 96 | 78.7% |
| (b) Organizing instructional materials | 98 | 80.3% |
| (c) Designing course website(s) | 56 | 45.9% |
| (d) Developing course materials | 94 | 77.0% |
| (e) Maintaining a developed course website | 68 | 55.3% |
| (f) None of the above | 5 | 4.1% |

* Q 2. Which of the following procedures are you involved in when delivering online instruction?

When analyzing faculty technology skills, the responses to Q3 showed that the faculty were confident in their technology skills needed to develop online instructional components of their courses. Question 3 required Likert scale responses to six (6) items (strongly agree --> strongly disagree) and the responses were converted to number systems in order to identify degrees of faculty technology skills. A score of 6 was assigned to “strongly agree” and the minimum score of 1 was assigned to “strongly disagree”. A mean score larger than 3.5 was considered positive. When analyzing the responses, faculty members’ competency in developing online instructional components appeared to be high ($M=4.03$), as Table 8 shows.

Table 8. Faculty Technology Skills as Reported by Faculty Respondents (N=129)

| Minimum score | Maximum score | Mean | SD |
|---------------|---------------|------|-------|
| 0 | 6 | 4.03 | 1.375 |

Q3. How do you rate your technology skills in developing designing and maintaining online courses or online components of your courses?

Table 9. Technology Skills by Age as Reported by Faculty Respondents

| Age | Mean | N | Rank | SD |
|---------------|------|-----|--------|-------|
| 1. 30 or less | 3.73 | 11 | Third | 1.421 |
| 2. 31-40 | 4.63 | 22 | First | 1.086 |
| 3. 41-50 | 4.33 | 39 | Second | 1.383 |
| 4. 51 or more | 3.63 | 57 | Fourth | 1.345 |
| Total mean | 4.03 | 129 | | .375 |

* Maximum score is 6 and the minimum score is 1.

* The mean score larger than 3.5 was considered positive.

When analyzing the data by four age groups ((a) less than 30 years of old, (b) 31-40 years old, (c) 41-50 years old, (d) 51 or more years old), group (b) ($M=4.68$) and group (c) ($M=4.33$) showed high confidence in using technology

for developing their blended courses while group (d) ($M=3.63$) and group (a) ($M=3.73$) showed relatively lower confidence than the other groups (see *Table 10*).

Table 10. Comparison of Technology Skills Between Age Groups

| Age Groups | | | |
|-------------------|------------|-----------------|------|
| Age (1) | Age(2) | Mean difference | Sig. |
| 31-40 | 51 or more | 1.050* | .010 |
| 41-50 | 51 or more | 0.702* | .010 |

* The mean difference is significant at the 0.05 level.

Table 11. Technology Skills by Rank As Reported By Faculty Respondents

| Position | Mean | N | SD |
|---------------------|-------------|----------|-----------|
| Assistant professor | 4.48 | 46 | 1.130 |
| Associate professor | 3.67 | 27 | 1.494 |
| Full professor | 3.89 | 47 | 1.306 |
| Instructor | 3.71 | 7 | 1.496 |
| Total | 4.05 | 127 | 1.327 |

Table 12. Comparison of Technology Skills Between Rank

| Position(1) | Position(2) | Mean Difference (1-2) | Sig. |
|---------------------|---------------------|----------------------------------|-------------|
| Assistant professor | Associate professor | .812(*) | .011 |
| Assistant professor | Full professor | .585(*) | .032 |

* The mean difference is significant at the .05 level.

When comparing the results by variables such as age and position, there were significant differences in the mean scores by age ($p < 0.01$) and rank ($p < 0.01$) among groups. The comparison of responses of four (4) age groups showed a significant difference between the groups ($p < 0.01$) (see *Table 10*). In particular, the LSD Tests revealed that there was a significant difference between the age groups such as 31-40 years of old age and 51 or more ($p < 0.01$) and 41-50 years of old and 51 or more ($p < 0.05$) in their skills in developing online instructional components.

When analyzing the data by faculty rank, assistant professors ($M=4.48$) expressed the strongest confidence in their technology skills and instructors ($M=3.67$), associate professors ($M=3.69$), and full professors ($M=3.81$) were confident in their skills in developing online instructional components, yet their confidence level was somewhat lower than assistant professors (see *Table 11*). When comparing the mean scores among the four (4) positions (instructor, assistant professor, associate professor, full professor), there were significant differences between the assistant and associate professor groups and between the assistant and full professor groups as *Table 12* above shows. Compared to the other groups, assistant professors revealed exceptionally strong confidence in their technology skills.

Of the five (5) respondents who reported no participation in any of the online course development activities, three faculty provided extra information regarding their strategies for online course delivery as follows:

One faculty member in the department takes the lead in developing the course websites for the required courses (e.g. theory, methods), and all faculty share the course websites to keep the consistency.

Most of faculty at the University use a locally developed program called Toolkit and do not need to be involved in developing activities.

Faculty mainly use email for assignment submission to provide feedback, using a course website developed by somebody else.

What are the faculty attitudes toward and perceptions of blended instruction?

In order to investigate faculty attitudes toward and perceptions of blended instruction, responses to the questions consisted of attitudinal and perception statements were analyzed. The items required Likert scale responses to six (6) items (strongly agree --> strongly disagree). The responses to the question were converted to number systems in

order to identify faculty attitudes and perceptions. A score of 6 was assigned to “strongly agree” and a score of 1 was assigned to “strongly disagree”. A mean score larger than 3.5 was considered positive.

Table 13. Faculty Attitudes Towards and Perceptions of Blended Instruction

| Items | Mean | SD | N |
|---|------|-------|-----|
| 1. I prefer classroom instruction to online instruction | 4.57 | 1.451 | 114 |
| 2. I like both online and classroom instruction | 4.09 | 1.570 | 111 |
| 3. Blended instruction can overcome the limitations of online instruction. | 4.72 | 1.218 | 109 |
| 4. I am motivated to try blended instruction. | 4.49 | 1.489 | 113 |
| 5. I am willing to learning new technology for my classes. | 5.09 | 1.211 | 115 |
| 6. Blended instruction is an option for students on or near campus only. | 3.42 | 1.714 | 108 |
| 7. Student learning outcomes care influenced by instructional delivery methods. | 5.17 | 1.116 | 115 |
| 8. Quality of instruction is influenced by instructional methods. | 5.05 | 1.329 | 114 |
| 9. I am regularly involved in online instruction | 2.99 | 1.998 | 111 |
| 10. I am regularly involved in blended instruction | 4.46 | 1.682 | 112 |

* Maximum score is 6 to be “strongly agree” and minimum score is 1 to be “strongly disagree”.

* The mean score larger than 3.5 is considered positive.

As shown in *Table 13*, respondents generally had positive attitudes toward blended instruction, and they perceived that blended instruction improves the quality of their instruction ($M=5.05$). Most of the respondents were motivated to try blended instruction ($M=4.49$), and were willing to learn technology necessary ($M=5.09$) as well. Furthermore, the faculty were favor of both online and blended instructional formats ($M=4.09$) and perceived that blended instruction could overcome the limitations of online instruction ($M=4.72$). Most faulty preferred classroom instruction to online instruction ($M=4.57$).

Consequently, while a large number of faculty were regularly involved in blended instruction ($M=4.46$), a low number of faculty were involved in online instruction only ($M=2.99$). Regarding faculty perceptions of blended instruction, faculty were regularly involved in blended instruction since they perceived that student learning outcomes were influenced by instructional delivery methods ($M=5.17$). Detailed information is presented in *Table 13*. In some cases, faculty preferred traditional offline methods, due to various instructional situations. Following is an example:

Students don't always, or perhaps seldom, prefer a course where they learn a lot because that's a lot more effort; students and faculty will continue to choose mostly lecture because it's much easier for both faculty and students; younger students often like to have strong direction and in an online setting they may feel more isolated and unsure of themselves.

Many faculty also commented that it costs extra time and effort to develop and maintain their course websites when pursuing blended instruction and that there should be institutional support or incentives to compensate for their extra work.

How do institutions support faculty involved in blended instruction?

In order to determine levels of instructional support for faculty in delivering blended instruction, responses to the question asking about the levels of instructional support, kinds of support, and institutional goals for course delivery were analyzed. When analyzing the levels of institutional support for using online technology, the results showed that the participating university representatives perceived that their institutions were very supportive in assisting faculty in developing and delivering online instructional components as *Table 14* indicates ($M= 4.42$, $SD = 1.37$).

Table 14. Levels of Institutional Support for Faculty in Using Online Technology for Teaching

| Item | N | Minimum | Maximum | Mean | SD |
|------|----|---------|---------|------|-------|
| Q4 | 33 | 1 | 6 | 4.42 | 1.370 |

*Q4. How do you rate your school’s support for faculty in using technology for teaching?

* Maximum score is 6 to be “very positive” and the minimum score is 1 to be “not at all.”

In order to examine the kinds of support provided by universities, responses to the questions about the kinds of institutional support were analyzed. Of the total 33 universities, 31 universities (96.9%) had a help desk for students

and faculty, 29 universities (87.9%) provided some kinds of help necessary for delivering online courses, 26 universities (78.8%) offered workshops about instructional design practices for different instructional delivery systems, and 24 universities (77.4%) provided instructional designers or specialists. However, only a fewer participating universities employed incentive systems (32.3%) to encourage faculty. Faculty were required to participate in certain training sessions or workshops prior to teaching online courses in only eight (8) universities (24.2%). Detailed information is presented in *Table 15*.

Table 15. Institutional Support for Online Course Development as Reported by the coordinators

| Item | Frequency (N=33) | Percent |
|--|---------------------|---------|
| 1. A help desk is available to students and faculty for assistance with technical problems. | 31 | 96.9% |
| 2. My university supports faculty in delivering courses online by providing necessary help of other kinds. | 29 | 87.9% |
| 3. My university offers workshops about instructional design practices for different instructional delivery methods. | 26 | 78.8% |
| 4. My instruction provides faculty an instructional designer or instructional technology specialist for online course development. | 24 | 77.4% |
| 5. My university offers incentives for faculty members who agree to deliver courses online. | 10 | 32.3% |
| 6. Faculty are required to participate in certain training sessions or workshops prior to teaching courses with online instructional components. | 8 | 24.2% |
| 7. My universities provides faculty with specific standards for online course development. | 7 | 21.9% |

In addition, several respondents who provided extra information reported that choice of format is left to faculty and departments; faculty make their own decisions regarding their instructional modality and the universities did not require faculty to employ certain types of instructional delivery formats. In other cases, the departments and programs decided to offer blended courses, yet the universities did not mandate any types of instructional formats in any centralized manner.

Regarding instructional goal(s) for course delivery, the participating universities desired to increase students' accessibility to their programs by increasing online instructional components or offering online courses. For instance, a majority of universities' goals were to increase the number of blended courses (63.3%), online degree programs (53.3%), and putting materials online (53.5%) in order to provide students with more options in their learning. Only one university responded that creating a fully developed virtual campus was the instructional goal. Detailed information is summarized in *Table 16*.

Table 16. Institutional Goals for Course Delivery responded by the coordinators

| Item | Frequency (n=33) | Percent |
|---|---------------------|---------|
| 1. Our goal is to increase the number of blended courses in order to provide students with more options in their learning. | 19 | 63.3% |
| 2. Our goal is to increase the number of online degree programs in order to increase student accessibility to our programs. | 16 | 53.3% |
| 3. Our goal is to put our course materials online as often as possible in order to complement classroom instruction. | 16 | 53.3% |
| 4. We do not have a specific goal for course delivery. | 5 | 17.2% |
| 5. Our goal is to create a fully developed virtual campus, not requiring class attendance. | 1 | 3.3% |

* What is your instructional goal in delivery of online or blended courses?

What are the challenges in supporting blended instruction?

In order to find out the biggest challenges in supporting blended instruction, questions about the challenges in assisting faculty in developing online courses and evaluation procedures were analyzed.

According to the data analysis (*Table 17*), the biggest challenges in assisting faculty in delivering blended instruction reported to be faculty workload (70.6%), lack of faculty motivation and enthusiasm(61.8%), and financial support

from school(26.5%). In order to examine whether there is an appropriate evaluation method available for blended instruction, question about the assessment method was analyzed. According to the data (*Table 18*), course evaluation procedures for blended instruction in the participating universities were not appropriately developed and were not available for the use of faculty and students in most of the participating universities; evaluation formats/instruments were available in only seven (7) universities (21.2%) of the total 33 universities surveyed. Evaluation forms for students and instructors were available in six (6) universities, and forms for instructors were available in two universities. Eleven (11) university representatives reported that they were not sure about the evaluation methods used by faculty (see *Table 18*).

Table 17. Challenges in Supporting Blended Instruction responded by the coordinators

| Statement | Frequency | Percent |
|--|------------------|----------------|
| 1. Faculty workload | 24 | 70.6% |
| 2. Lack of faculty motivation and enthusiasm | 21 | 61.8% |
| 3. Financial support from school | 9 | 26.5% |
| 4. Insufficient infrastructure | 4 | 11.8% |
| 5. Lack of equipment | 1 | 2.9% |

Table 18. Assessment of Blended Instruction as Reported by coordinators

| Item | Frequency | Percent |
|--|------------------|----------------|
| 1. Forms available for both students and instructor. | 7 | 21.2% |
| 2. Forms available for students only | 6 | 18.2% |
| 3. Forms available for instructors only | 2 | 6.1% |
| 4. No forms available | 7 | 21.2% |
| 5. Not sure | 11 | 33.3% |
| Total | 33 | 100% |

* Are appropriate instruments available to students and instructors for evaluating blended courses?

There was no significant difference found in the use of evaluation methods for blended instruction by university type, when analyzing the data with a T-test, ($p>0.05$). Since blended instruction is a fairly new concept and not adopted broadly as a format for instruction in many universities, appropriate course evaluation forms and procedures did not seem to be available, or else many university staff are not familiar with the evaluation instruments available in their universities.

Conclusion

The purposes of this study are to examine faculty involvement in blended learning instruction and their attitudes towards this instructional method. The study also explored how universities support faculty in their current practices on blended instruction and the challenges involved in supporting faculty.

The most common instructional delivery format used by the universities and their faculty was classroom instruction using online instructional components as supplementary materials. Blended instruction has become a common instructional delivery format in most universities, yet appropriate procedures or instruments for evaluating blended instruction were minimal in most universities. More than 50% of the participating universities have a goal to increase student accessibility to their programs by increasing the number of blended courses or placing institutional materials.

Most faculty were actively involved in blended instruction by designing course content, organizing instructional materials, and developing course materials, and felt comfortable using technology. However, differences were found in the levels of technology competency in different faculty age groups and levels. Assistant professors between the ages of 31-40 expressed the highest confidence level compared to other groups, but associate and full professors had relatively low confidence in their skills. This study is congruent with the findings of previous studies (Chai and Lee, 2008) that age is one of the important factors that affect faculty attitudes towards technology. Faculty who did not participate in online course development activities employed commercially developed programs or shared websites developed by colleagues for the same courses.

Faculty who participated in this study perceived that blended instruction improves the quality of their instruction. The majority of faculty strongly believed that blended instruction can overcome the limitations of online instruction and was willing to learn the necessary technology skills for their classes. While previous studies (Ellis et al., 2006; Gerber et al., 2008; Papanasasiou & Angeli, 2008) often point out that faculty attitudes toward using technology is one of the obstacles in employing online instructional components in particular, this study revealed that many faculty are participating and have the willingness to improve instructional quality by being involved in the developing and delivering process.

However, ironically, the technology coordinators reported a lack of faculty motivation and enthusiasm as the biggest challenges for the universities. This lack of motivation may be due to the lack of incentive system in most universities as Donoghue (2006) and Restauri (2007) discussed. When analyzing university support, most universities seemed to be supportive in assisting faculty, providing online help desk, faculty workshops, and necessary technical help. Despite this support, only 32% of the participating universities provide incentives for faculty who agree to deliver courses online. This shows that problems such as lack of policies for providing promotions or incentives still resides. It is clear that current challenges for administrators of higher education institutions are to provide incentive systems to get more faculty to involve and adequate support for faculty who are already motivated or adopt blended instruction to be more actively engaged in the instructional delivery method.

As discussed in this study and the literature (Howell et al., 2004), there is a critical need for institutions to change their support systems. If universities want to effectively involve faculty in their transformation efforts, they must align their institutional goals with faculty evaluation systems and promotional policies that improve faculty motivation (Howell et al., 2004; Tabana & Johnsrud, 2008; Wagner et al., 2008). If universities do not have any incentives for extra workloads or do not provide any adequate instructional support, faculty members may not take the risks associated with blended instructional method.

Recommendations for Future Research

This study has provided valuable information for higher education institutions as they seek to develop technology based-courses. Among other findings, this study identifies the issues of evaluation of blended instruction that has been neglected in other studies. This study provides institutions with insight into faculty perceptions of institutional support, instructional situations, and needs in the area of blended instruction. Technology coordinators may better understand from the study what they need and how to support them in pursuing their instructional goals. However, more research is needed in order to better understand the use of blended instruction to enhance learning and teaching practices. Therefore, it is recommended that (a) this study should be replicated and extended to different classifications of universities; (b) the effect of incentives on participation rate in this sample and other should be conducted; and (c) a way to share best practices and evaluation should be conducted.

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EduBingo: Developing a Content Sample for the One-to-One Classroom by the Content-First Design Approach

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ABSTRACT

The successful adoption of technologies in classrooms, we argue, relies on a greater emphasis on content-related pedagogical models for technology enhanced learning design. We propose the *content-first design*, an approach to creating content sample in the one-to-one classroom—classrooms with a wireless enabled computing device available for each student. To demonstrate this design approach, we take arithmetic calculation (fractions, multiplications, divisions, etc.) in elementary schools as the subject domain with EduBingo, an educational game system played in one-to-one classrooms. The system allows the teacher to monitor the accuracy and speed of the student answers during a game session, and the students can reflect on their answers after the game. Two trial tests are described, one focusing on the students while the other on the teacher. The first test indicates that the students make progress on arithmetic fluency from one session to another and that the game promotes positive affect; the second illustrates how a teacher felt the game fit into her classroom practices. This paper emphasizes those considerations that are most vital to the content-first design approach proposed herein.

Keywords

Content-first design, Technology enhanced learning, One-to-one classroom, Bingo game, Procedural fluency

Motivation

More than twenty years ago, one of the authors of this paper used a Lisp machine, which cost fifty-thousand US dollars, to implement an intelligent tutoring system prototype for his doctoral research. After a trial test by his two friends, he wrote and published a few papers, then graduated. But such computers were far too costly for any real world practice in the 80's. Furthermore, new models emerged every two years—computers evolved rapidly at that time—and hardly any portion of the system implemented could be reused. Except for a legacy of ideas, in the form of published papers, nothing was left. This was a typical scenario of *dream-based research*, in which researchers explore potential opportunities that innovative technology might someday provide to reform education in the future—often a distant future. This story provides an early glimpse at some of the difficulties involved in efforts to transfer results from research in the field of technology enhanced learning.

Today, innovative technologies continue to breathe new life into dream-based research. A large number of researchers in the field are still delving into it. On the other hand, more and more people can afford to own powerful computing devices for their personal use, bringing the advent of the one-to-one (1:1) classroom: classrooms where every student uses at least one wirelessly connected computing device (Chan *et al.*, 2006). This, for the first time in history and despite all sorts of technological and societal challenges, gives rise to the *adoption-based research*—research that works towards the adoption of technology enhanced learning in real world educational settings, both

formal and informal (Chan *et al.*, 2006; Liu *et al.*, 2003; Roschelle, Penuel, & Abrahamson, 2004; Zurita & Nussbaum, 2004).

Compared to other social sectors, such as commerce, industry, civil services, entertainment, and others, education, especially schools, is perhaps the slowest sector to enter the digital era. Furthering this pessimistic view was a study mandated by the United States Congress on a large scale evaluation of educational software—15 reading and mathematics products used by 9,424 students in 132 schools during the 2004-2005 school year (Paley, 2007). The study, as measured by their scores on standardized tests, compared students who received the aid of technology with those who did not. No statistical difference was found. Some researchers have speculated that these commercial products might not be fully exploiting the real power of digital technology for learning. However, Halverson and Collins (2006) argued, despite the catalytic power of information technology, schools, being social institutes, may leave their core practice untouched. Nevertheless, researchers have reported positive successes (Abowd, 1999; Anderson *et al.*, 2003; Dufresne *et al.*, 1996; Gay *et al.*, 2001; Huang, Liang, & Wang, 2001; Liu *et al.*, 2003). Additionally, many researchers believe that, as shown in the first debate on the Internet organized by the magazine Economist (Cottrell, 2007), the new medium of digital technology will ultimately bring about a completely different form of schooling.

Adoption is hard, so is adoption-based research. By any significant measure, the research community has not started adoption-based research yet. Although many exciting programs and advances have been proposed, the progress resulting from decades of funded studies has not resulted in “pervasive, accepted, sustainable, large-scale improvements in actual classroom practice, in a critical mass of effective models for educational improvement” (Sabelli & Dede, 2001). The majority of our research is still being conducted in laboratories where we design systems either for online collaborative learning or for individual learning or tutoring. Researchers, not the school, leave the classroom, the place where formal education mostly takes place, untouched by information technology. In reality, only a few researchers have entered classrooms, taking a classroom as a research unit for design and investigation, establishing research examples of the adoption of technology in classrooms. Nevertheless—with the emergence of 1:1 classroom technology, with the call from society for adopting technology in education, with the calls from the funding agencies, the wheels of doing adoption-based research are starting to turn.

In this paper, we argue that adoption-based research demands a change in the emphasis of research, not the technology first, not the experiment first, but the *content* first—taking content design, grounded in theories, in 1:1 classroom settings as the first priority, and leaving technological implementation, experiment, and refinement for later. In particular, we introduce the content-first design approach to 1:1 classroom research, emphasizing four design concerns: content sample identification, learning assessment goal, learning flow, and teacher adoption. We describe the rationales of these concerns and exemplify them by detailing the design of EduBingo for the 1:1 classroom. Subsequently, we describe two trial tests of EduBingo, and, finally, give our concluding remarks.

Content-First Design and Content Sample

The term “content” in this study broadly refers to pre-designed learning activities associated with materials, that is, *content = material + pre-designed activity*. The broadness of this definition intends to emphasize that content is not simply codified knowledge (material) such as static web-pages. Both the material and the learning activity (pre-designed activity) should be considered in conjunction, providing the means of how the material is used in the activity. For example, reading a book is a content, in which the articles in the book are the material, and the activity reading is the pre-designed learning activity. Thus, materials are information or semiotics embodied in the paper medium, which compose the book, and the pre-designed activity is the reading of the book by a reader. In the foreseeable future, classrooms will continue to rely on textbooks. How to transcend the current classroom’s practice that mainly uses textbooks to the 1:1 classroom practice that mainly uses learners’ devices is the key issue.

A variety of issues are inherent in attempts to shift to a 1:1 classroom practice. In the real world practice, teachers, however, mainly care about the subject matter—their teaching of the subject matter and the coverage of the subject matter—more than anything else. Effective teaching models must be subject domain dependent. This is indeed the essential concept of pedagogical content knowledge (PCK), the knowledge of teaching which lies at the intersection of subject domain and pedagogy (Shulman, 1986). It includes “an understanding of how particular topics, problems, or issues are organized, presented, and adapted to the diverse interests and abilities of learners, and presented for

instruction” (Shulman, 1987, p.8). Thus, it reflects the capacity to transform the domain knowledge into forms that are pedagogically powerful and yet adaptive to the students.

Four interdependent concerns are primary to content-first design—content sample identification, learning assessment goal, learning flow, and teacher adoption—each of which relates PCK to some extent. We chose elementary arithmetic calculations as our content sample. In the following sub-sections, we discuss these four concerns alongside the content sample.

First concern: Content sample identification

Given that there are no essential differences between the 1:1 curriculum and a traditional curriculum, we begin by selecting a portion of the traditional curriculum that is to be transformed into the 1:1 content sample. Usually a curriculum can be decomposed into different parts; a content sample may then be developed for each part. However, consideration of the relation of a content sample in a complete 1:1 curriculum is useful; once content samples across the curriculum have been established, they are assembled and expanded to form a complete 1:1 curriculum. In the process of developing a complete 1:1 curriculum, the curriculum is scaled up in collaboration with teachers.

Arithmetic calculations as a content sample

To exemplify the content-first design in a 1:1 classroom, we take the arithmetic calculations—addition, subtraction, multiplication, and division—as a content sample. This content sample is an essential topic in the mathematics curriculum from the first-grade to the fifth-grade. Success in one subtopic in arithmetic calculations could be built upon to extend to related subtopics and to the mathematics curriculum in other grades.

Second concern: Learning assessment goal

If content sample identification talks about what to learn, then learning assessment goal speaks of how well to learn. As Shulman (1987) has shown, PCK research reveals that we should distinguish what to learn from how to learn it. Additionally, there is often another specific concern—how well to learn. Emphasizing that this is measured by individual progress towards meeting assessment goal, this concern directly affects pedagogical design. Only by targeting the assessment goal in the design, can we know what material is needed and what pre-designed activity is appropriate for the content sample. Striving to fulfill the assessment goal, a content sample should be designed and re-designed, experimented and re-experimented in order to seek continual improvement.

Fluency as an assessment goal

In the elementary mathematics, education researchers expect students to acquire a set of capabilities: conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition (National Research Council, 2001). Concepts, procedures, problem solving strategies, and reasoning are what to learn; whereas understanding, fluency, competence, adaptability, and productive disposition are how well to learn, which, in turn, give us a set of assessment goals. Some mathematics educators and researchers define procedural fluency as “*skill in carrying out procedures flexibly, accurately, efficiently, and appropriately*” (National Research Council, 2001, p.116). In this study, fluency, our assessment goal, is limited in arithmetic accuracy, which is the ratio of correctly answered problems to all answered problems, and efficiency, which is the average time of answering a problem.

Third concern: Learning flow

Learning flow concerns how to learn, aiming at engaging students in a pre-designed sequence of activities interwoven with the material. Whereas this sequence is traditionally called a lesson plan, learning flow draws attention to the central need to maintain flow in 1:1 classrooms. Fortunately, researchers have already developed a rich repertoire of pedagogical activity models over the years. Technology, as a component of 1:1 classroom settings,

can further enable the design of these models. Once learning flow has been specified, designers work closely with subject matter experts to implement the details, including the associated material operated in each activity model of the flow.

Learning flow is composed of some basic 1:1 classroom activity modes, including individual, group, inter-group, one-to-class, class-to-one, group-to-class, class-to-group, etc. An example of the individual mode is that every student in the classroom learns quietly with his/her computing device. The device may act as a cognitive tool, an intelligent tutor, or an online information browser. Students have no interaction with others inside the classroom except for the teacher. An example of the class-to-one mode is anonymous answering (or voting) for a multiple choice question, which requires students to make choices on their clicker devices while the teacher is playing the role of a coordinator or judge (Huang, Liang, & Wang, 2001).

Bingo game as learning flow

Well-timed practice is essential for building procedural fluency in arithmetic calculations as well as other skills (Dick, Carey, & Carey, 2001; Gagne, 1985; Gagne, Briggs, & Wager, 1992). However, arithmetic drills render students prone to boredom (McLeod, 1992), make students either distracted or impatient, lower their learning interest, and consequently run contrary to the assessment goal—developing fluency. Game-based pedagogies can effectively shift students' attention from performing repetitious and boring tasks to winning a game, thereby maintaining their engagement in the learning tasks.

We adopt the Bingo game as the learning flow for our content sample for a number of reasons. First of all, it remains to this day a highly popular game, widely played for fun, gambling, and education, with a long history (Delind, 1984; Snowden, 1986). Bingo was initially adapted from a variation of Lotto, namely Beano. In 1929, Edwin S. Lowe, a New York toy salesman, unwittingly came upon a carnival where Beano was being played. It was so popular that he could not get a seat to play. He observed that the players were so addicted to the game that they were reluctant to leave until the pitchman closed the game at three in the morning. At a later observation of the game, Lowe noticed an accident: a player mistakenly yelled "Bingo" during the game when she won. Lowe then started to promote the game under the name Bingo.

Another reason is that Bingo is appropriate for extensive practice—repeating a simple learning task assigned by the teacher. Furthermore, winning the Bingo game requires luck, besides other factors. This lessens the frustration of those students who lose. Finally, Bingo requires a coordinator, identified as the caller. The teacher can naturally play this role (more discussion in the next sub-section).

The learning flow of EduBingo, our realization of the Bingo game in a 1:1 classroom, mainly consists of a teacher's dispatching arithmetic problems and students' answering of those problems (the teacher's dispatching is in one-to-class mode and the students' answering is in individual mode). Figure 1 shows the flow of EduBingo in the 1:1 classroom.

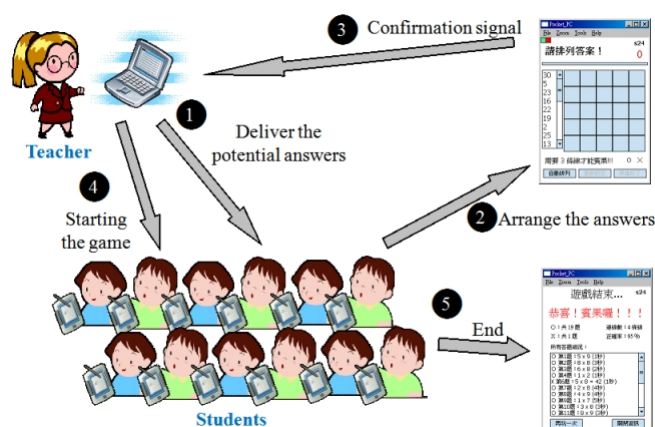


Figure 1. Learning flow of EduBingo

Steps of the learning flow

1. The teacher uses a handheld device to initiate a game session, delivering all potential answers to students' devices.
2. Students' devices receive the answers from the answer pool. Each student arranges those answers on the answer board (see Figure 2).
3. Each student sends out the confirmation message to inform that she is ready to play.
4. The teacher starts the game. A loop of delivering a problem by the teacher and answering the problem by each student is performed, and it cannot be stopped until one student gets "BINGO!" or no more problems can be delivered.
5. The session ends. The students can have a time of reflection according to the system statistics (see Figure 3).

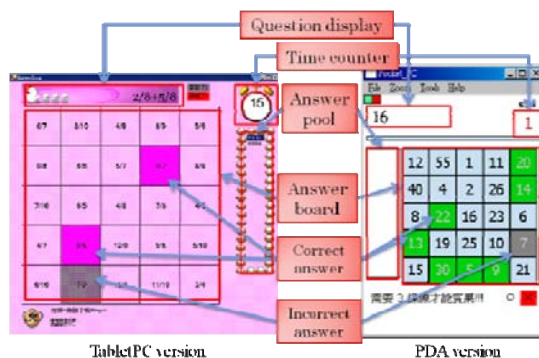


Figure 2. EduBingo board Interface

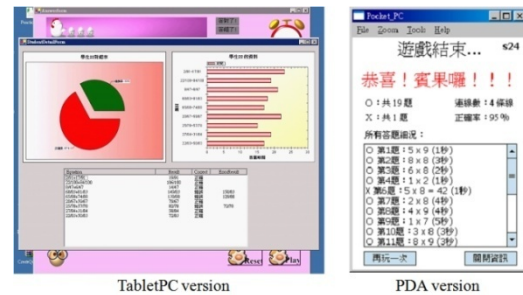


Figure 3. Interface of individual session record after the game session

Fourth concern: Teacher adoption

Remarkable fulfillment of the learning assessment goal cannot guarantee successful adoption. Teachers do not only decide what and how their students learn, but also decide whether technology should go into their classrooms or not. On the one hand, they reject technology adoption for many reasons: not ease of use, changing their daily practice too dramatically, not enough professional training, increasing their work load, even if just slightly. On the other hand, they seek increases in teaching productivity, for example, having computers take care of the lower level tasks so that they may concentrate on higher level tasks such as making decisions for the whole class or individual students. It is our view that increasing productivity is the essence of all technological innovations. Therefore, in addition to the emphasis on measuring the progress of each student towards learning assessment goals, teacher adoption factors are taken into account in all phases of design and evaluation.

Obviously, the teacher's role in a 1:1 learning flow strongly affects his or her mindset towards adoption. In fact, like a traditional classroom, the teacher in a 1:1 classroom plays indispensable roles—the coordinator, the monitor, the leader, the facilitator, the judge, and the personal guide. Furthermore, teachers make students feel valued in the classroom, and they stimulate engagement in the learning tasks (Morganett 1991; Pigford 2001). Even in the individual learning mode, a teacher actively monitors the real time progress of the whole class and makes decisions about actions to be taken for individuals with special needs.

Teacher adoption of EduBingo

The design of what the teacher has to do in EduBingo defines his or her role in that activity. The teacher takes control of the Teacher Supervising Center Component, consisting of Coordination Subsystem (see Figure 4) and Authoring Subsystem (see Figure 5). As a monitor, a teacher uses the Coordination Subsystem to oversee accuracy and efficiency data for each student of the class. The teacher, assuming the role of leader, can start, pause, or end an EduBingo session at any time. To form the problems used in a new session, the teacher composes new calculation problems in the Authoring Subsystem, and may draw upon existing problem sets in the Material Bank.

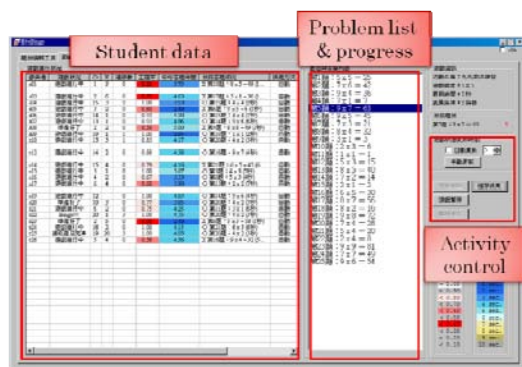


Figure 4. Coordination Interface

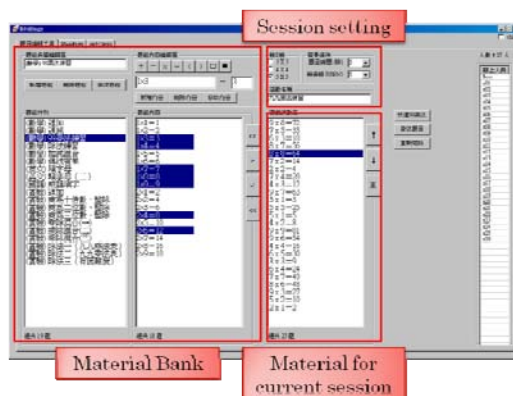


Figure 5. Authoring Interface

Trial Tests

In order to inform the future improvement of the content sample, two trial tests of EduBingo were undertaken in two elementary school classes, one fourth-grade and the other third-grade. The fourth-grade class practiced fraction arithmetic; the third-grade integer multiplication and division. The first test focused on the students while the second centered on the teacher. The students used Tablet PCs in the first test and PDAs in the second, whereas both teachers in the two tests used a Tablet PC. The following sections describe the design and results of these two tests.

Trial test 1: Student fraction fluency

There were 22 students in the class, twelve boys and ten girls. However, one student data was lost due to unexpected system problems. The trial test started with a five minute introduction to the system. After familiarizing students with the system through playing two warm-up game sessions, no arithmetic calculations but the traditional number matching, the students engaged in two game sessions for practice in using 5×5 matrices EduBingo board in 30-second and 20-second time limits for the first and second sessions, respectively, with the same difficulty level of problems. The winning condition was set as two lines, vertical or horizontal or diagonal, of correct answers on the board.

All students were asked to fill out a questionnaire after the sessions. The students' data log and questionnaires were used to assess the issue addressed by the test. The two real-practice game sessions were compared to examine the improvement in accuracy and efficiency of the fraction arithmetic operations. The students' affect was also explored from the results of the questionnaire.

Results

Figure 6 displays the accuracy and response times in the two practice sessions. The accuracy was calculated as $(\text{number of correct answer} / \text{number of answers attempted}) \times 100\%$, and the response time was calculated as the average time spent on answering all problems in a session. After the second session, over half of the students (13/21) improved in accuracy (see Figure 6a). The majority of students (16/21) were able to reach the ceiling (100% accuracy) in the second session. It should be noted that after the first session, there were 15 students whose performance was not at the ceiling; however, among them, there were 11 students that reached the ceiling after the second session. It was a bit surprising to us that there were 3 students whose accuracy decreased in the second session. The accuracy drop of student 19 and student 20 might be due to slips (careless answers), but the reason for the unusually large drop (around 30%) of student 20 is unknown to us, albeit due to capers. For response time (see Figure 6b), all the students could answer the problems in both sessions within the given time limits, while most students had similar response times in both sessions, even when the time limit was shortened. The comparison shows that most students improved their accuracy in answering fraction arithmetic problems through practice and maintained their efficiency in performing the tasks on average.

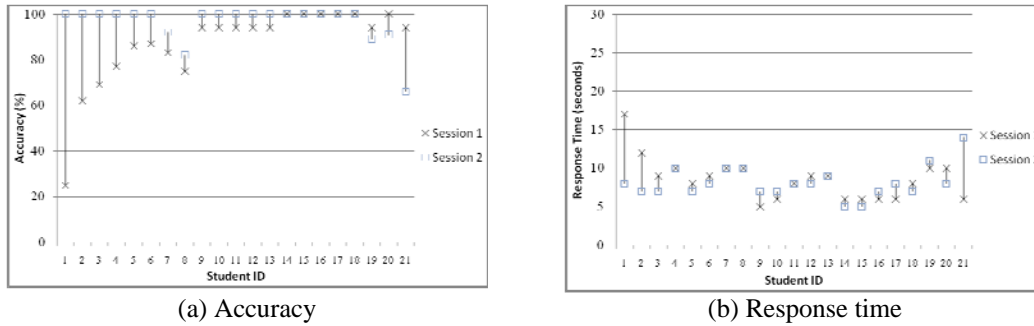
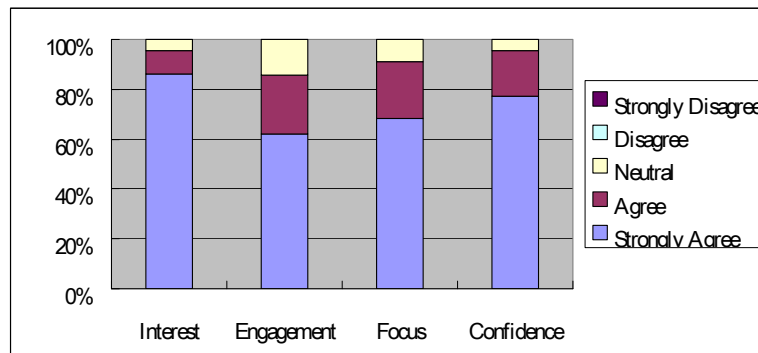


Figure 6. Accuracy and response time between the two practice sessions

The questionnaire contained questions of four dimensions to explore the students' affect. All students showed positive reactions for all dimensions (see Figure 7): When asked to compare EduBingo with paper-based practice exercises, 20 students thought that they would be more interested in EduBingo; 18 more engaged; 19 more focused; and 20 more confident. Twelve of the students indicated that they would learn and practice with more efforts to be able to perform well in EduBingo.



Trial test 2: Teacher adoption

The second trial test investigated teacher adoption issues. After familiarizing the students with the system through playing one warm-up traditional Bingo session, two sessions for memorizing multiplication table facts and two sessions for practicing division of integers were led by the teacher, with time limits of 10, 8, 50, and 30 seconds, respectively, for each session. Because of the limited PDA screen size, all four game sessions used 4×4 matrices. The teacher was interviewed after the test.

Results

The teacher was positive toward EduBingo adoption, as indicated in the following interview protocol.

Interviewer: Is the system helpful for student monitoring?

Teacher: Teachers are concerned about student learning. The problems I prepared for the sessions have not all been used. For example, when a student Bingos, the game is terminated, leaving some problems unused.

Interviewer: EduBingo provides an option that allows the game to continue even if someone Bingos. This way, students can practice all the problems you prepare for them.

Teacher: Ok! That means I can use EduBingo for teaching and quizzes.

It is noteworthy that the teacher's primary concern was student learning and whether the system functionalities can support it.

Teacher: Is it possible to allow students to compose problems and take on the role of the caller?

Interviewer: Yes, it is possible to add these functionalities to EduBingo.

Teacher: Good! This would allow the teacher to spend more time on students in need.

Teacher: It is a pity that the teacher has to stay in front of the screen all the time. In addition, due to the short period of time for answering problems, it is impossible for me to observe students' behavior. If the students are allowed to play the role of the caller, the teacher will be able to spot poorly performing students.

The teacher was also interested in whether EduBingo supported functions that allow students to compose problems and be able to conduct the activity on their own, so that she could pay more attention to those students that need help. In addition, she desired a monitor function to assist in locating the students who need help. Both supporting functions suggested by the teacher can be added in the future version of EduBingo. The teacher felt the Tablet PC was too heavy for her to carry when moving about the classroom. This can easily be resolved by using a light handheld device.

Interviewer: Did the system provide sufficient information for conducting the sessions?

Teacher: EduBingo provided a good interface for revealing the status of the whole class during the process; different colors indicated student performance. However, I need to know more details about how the students are learning. For example, I want to know if students are answering by guessing. The statistical information cannot provide me with information about whether a particular student was able to answer a problem or not. If a student is frustrated too much when encountering difficult problems, he will give up.

Teacher: Just-in-time assistance is essential in instruction, especially for students with low performance. If just-in-time assistance cannot be provided, more time is needed for remediation.

The teacher confirmed that monitoring information displayed on her device during the sessions was beneficial. However, the teacher suggested that more information should be provided to facilitate individualized instruction.

Interviewer: How do the students like EduBingo for practicing arithmetic calculations?

Teacher: They loved it very much. Maybe EduBingo is similar to some games they often play. You may also consider designing games similar to Mario Bros. for practicing basic arithmetic calculations.

Finally, the teacher confirmed that the students enormously enjoyed EduBingo and appreciated the design of such a game-like system for learning.

Discussion of Trial Tests

As stated above, the main goal of the two trial tests was to gain valuable data that could be used to shape EduBingo according to the perspectives of students and teachers. According to the results shown above, EduBingo was an effective means to improving arithmetic accuracy but not efficiency. Contrary to our intuition, efficiency was not improved even after repeated practice, which may be attributable to the lack of time constraint on the answering of problems. In order to induce greater gains in improving accuracy, slips may be reduced by requiring students to readdress problems that are answered incorrectly.

In addition to the quantitative measures of accuracy and efficiency, students in the first trial test responded to EduBingo with positive attitudes. Researchers were able to confirm that students were fully engaged when playing EduBingo. Moreover, students maintained high levels of interest, attention and confidence when practicing

arithmetic calculations with EduBingo throughout the practice sessions. Positive student affect leads to a high motivation to learn, and is in turn essential to successful learning (Prensky, 2000). We feel that the greatly positive attitude towards EduBingo and high interest in it were not entirely due to the novelty effect of using computers in classroom. In the annals of Bingo history, it has been reported that crowds of people played Bingo games for extended periods of time (Snowden, 1986). Bingo's attraction derives from its characteristic influence on people to remain engaged in its game-play, but whether all students in a class can maintain such enthusiasm for EduBingo over long periods of time merits further investigation. No matter the results of such studies, positive student affect should be considered as a future learning assessment goal to be evaluated in addition to the data received from the students, ensuring more than achievement-based criteria to be satisfied.

The teacher's suggestions, along with the student data, have provided a direction for future improvements and modifications of EduBingo. Reflections on the comments given by the teacher suggest that an improved system should incorporate a mechanism to assist teachers in locating those students in need of help. For example, a student's unusually long time in answering a problem or a sudden increase in the rate of erroneous answers would trigger a detection that is sent to the teacher indicating a student is in need of help. All teachers desire to help students, directly and indirectly, but cannot do so if they are fully occupied with the logistics of a system. In addition, because a teacher cannot be expected help several students in need simultaneously, when possible, the system should utilize intelligent tutors.

Finally, EduBingo is easy to learn and play. The students in the two trial tests only spent a short period of time in the warm-up sessions in order to be familiar with EduBingo, even if some of the students had never played any Bingo game before.

Concluding Remarks

In this paper, we presented our initial guidelines for adoption-based researchers seeking to design and implement 1:1 classroom learning. In particular, we argue that design considerations should place content as the first priority. The primary concern of teachers is teaching effectively, not the cutting-edge technologies that can be introduced into a classroom. In other words, technology enhanced learning should begin by identifying what is to learn, that is, the content sample, then elucidating how well to learn that sample as a learning assessment goal. Next, a learning flow is designed with particular attention to the consideration of adoption by teachers. In our study, elementary level arithmetic calculation was identified as the content sample, and arithmetic fluency was the learning assessment goal. The game of Bingo was used to support the learning flow, and EduBingo was designed and implemented to realize this flow by providing a number of roles for a teacher.

The two trial tests shed light on possible future improvement. As accuracy is obviously more important than efficiency, to diagnose probable erroneous arithmetic calculation procedures in the gaming process and to remedy them between successive game sessions will be our immediate task in enhancing EduBingo. Moreover, as teaching arithmetic calculation procedures necessarily precede practicing such procedures, the incorporation of this teaching into the learning flow including EduBingo is the next major design task. Once this content sample has reached the stage that it is recognized by practitioners as a compelling sample, the use of EduBingo can be expanded to encompass more of the curriculum by working together with teachers to develop materials.

Content-first design can be extended as a general model of design; however, we limit its scope for 1:1 classroom settings so that we can focus on adoption-based research for designing content sample. For instructional design, ADDIE (Molenda, 2003), including Dick and Carey's version (Dick, 1996; Dick, Carey, & Carey, 2001), presents a generic conceptual framework that describes the five phases of instructional planning and creation—analysis, design, development, implementation, and evaluation. There are some correspondences between the content-first design approach and the ADDIE model. For example, both the content sample identification concern and the learning assessment goal concern correspond to the analysis phase; both the learning flow concern and the teacher adoption concern relate to the design phase. Content-first design does not particularly emphasize development, implementation, and evaluation as ADDIE does since they inevitably require iterations for design. However, content-first design places special emphases on putting the learning assessment goal at the outset and treating teacher adoption as an essential part of the design.

Nevertheless, we believe that refinement of this approach will continue as we gain more and more 1:1 research and practice experience. It is true that the learning assessment goal is a good device for gathering information and hence ideas for the subsequent design iterations to improve the content sample. However, there could be hazards or distortions of education (Hussey & Smith, 2002) if learning outcomes are overly emphasized as the primary concern in the design. Actually, the learning assessment goal should not only consider the learning outcome, but also take the learning process into consideration, for example, the student's enjoyment in the process. As such, the definition of the 'learning assessment goal' should be appropriately related to the overall educational goal. Furthermore, developing or adopting an evaluation model such as the Kirkpatrick model (Kirkpatrick, 1998) will help form a firmer foundation for the assessment goal.

Learning design (Koper, 2006; Koper & Tattersall, 2005), an emerging endeavor, aims to describe learning activities in a systematic and machine interpretable representation. A standardized modeling language will allow more flexibility on the part of designers to reuse and share learning activities. In association with learning design, a learning flow so specified could be packaged as a component and adopted into other content samples in different contexts. As this is an emergent issue in the field of adoption-based research, it has not been included in our current study. Learning flow in the content-first design approach currently concerns the design of a sequence of learning activities that achieve the learning assessment goal for an identified content sample.

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